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EAGLE PLUS

AIR SUPERIORITY INTO THE 21ST CENTURY

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Preface

The F-15C is the world's finest air superiority fighter. This aircraft provided coalition forces overwhelming air superiority during the Gulf War. However, in today's climate of reduced funding and military downsizing, a hard-look is required to determine the F-15C's mission effectiveness into the twenty-first century. These problems must be solved. Maintaining air superiority during the next conflict is critical for the United States Armed Forces and the F-15C will be on center stage in the air-to-air arena.

We would like to thank Lt Col Rita Springer, our research advisor, for assisting us in identifying the proper methodology and analysis procedures. She was unselfish with her many contributions to our project.

We give special thanks to the F-15 System Program Office (SPO) at Warner-Robins Air Logistic Center. Their F-15C maintenance and funding data provided the core of our readiness chapter. The database generated by Mr. Jeff Hill served as the foundation of our statistical analysis. Special thanks go out to Mrs. Betsy Mullis, LFLL branch chief, and to Mr. Jerry Vaughn, LFLV branch chief, for their individual contributions on logistics issues. Capt Arnold Lee was a focal point for our secondary structures investigations. Also, Mr. Ben Hollingsworth, F-15 SPO financial analyst, provided outstanding advice and data for our investigation into funding shortfalls.

In addition, we must recognize several contractors for their contribution to the research project. Ms. Lynn Grile, reliability analyst for Dynamic Research Corporation,

collected F-15C and F-16 maintenance data for maintenance statistical comparison. Mr. Rick Foster, a McDonnell Douglas structural engineer, provided excellent support for our airframe and structures studies.

Col Ron Hassan, Air Combat Commander chief of staff, provided the necessary guidance for the implementation of this study. Col Hassan identified the research parameters and provided the initial vision that started our long research journey. We appreciate his help in making this research project possible.

This study was much more than a course requirement for Air Command and Staff College (ACSC). Three of our four team members served in F-15C squadrons prior to their ACSC assignment. They witnessed the effects of aging aircraft and funding shortfalls on the young men and women who maintain and operate the F-15C Eagle. We felt an obligation to these very dedicated NCOs and airmen. We dedicate this research project to those many professionals who "keep 'em flying."

Abstract

The objective of this study was to determine if the F-15C could sustain the air superiority mission into the twenty-first century. Research focused on the three pillars of military capabilities as outlined in *Air Force Manual 1-1*. It analyzed F-15C short-term readiness factors, the F-15C force structure applied to a two Major Regional Conflict (MRC) scenario, and the need for F-15C subsystem upgrades.

This study resulted in three conclusions. First, F-15C readiness is adequate, but funding shortfalls and poor subsystem reliability has decreased the fully-mission-capable rate. Although the funding shortfalls were reversed, poor reliability in the radar, propulsion, and structure subsystems continue. Second, the current force structure of 300 operational F-15Cs is adequate for a two—MRC scenario. The involvement of a peer competitor, such as Russia or China, overextends the current F-15C force structure. Third, the F-15C can fly to 2010 or beyond if the radar, engine, and structure subsystems are modernized.

The F-15C and F-22 will play an important air superiority role into the twenty-first century if two courses of action are initiated. First, the recent decline in maintenance indicators must be reversed through a robust subsystem modernization program. Second, the F-22 must be procured to overcome the recent adversary advances in fighter technologies. Although growing budget constraints will make these courses of action difficult, they must be undertaken if the US is to maintain its air superiority edge.

Chapter 1

Introduction

> *Anyone who has to fight, even with the most modern weapons, against an enemy in complete command of the air, fights like a savage against modern European forces. With the same handicaps and with the same chance of success.*
>
> —Field Marshall Erwin Rommel

The maintenance officer shoved his hands deep into his pockets as he leaned forward against the gusting north wind. The journey from the flightline to the hangar seemed exceptionally long this arctic morning. The crew chief had just informed him aircraft 9078 was non-mission–capable (NMC) because of a bad heat exchanger. No replacement part was available in the supply system. They were down to eight good F-15Cs and needed to fly an 'eight-turn-eight' on Monday. If he could only get his six jets back from the Turkey deployment—life would be so much easier. It was not the lack of parts or the lack of aircraft that really concerned the maintenance officer. It was the look on the crew chief's face that bothered him the most. They both understood that cannibalizing a heat exchanger meant another weekend in the hangar for the young crew chief—his third in the last month.

This short tale depicts a microcosm of today's F-15C units. A shortage of parts, increased breakrates, quality-of-life concerns, high operations tempo and reduced force structures all occur daily at F-15 bases worldwide. Not all F-15 bases possess gusting north winds, but they do have the persistent problems of meeting daily flying schedules with aging aircraft.

This paper investigates the F-15C and its air superiority mission into the twenty-first century. The Department of Defense (DOD) defines military capability as "the ability to achieve a specific wartime objective". It regards military capability as being comprised of four components or pillars. The four pillars are readiness, sustainment, force structure, and modernization.[1]

Air Force Manual 1-1 defines the four pillars of military capabilities.[2] Readiness is the ability to accomplish mission objectives. Sustainment is the ability to sustain combat operation for a desired period of time. Force structure refers to the unit composition. Finally, modernization is associated with the aircraft's technological sophistication.[3]

This research paper is organized into three chapters addressing readiness, force structure, and modernization. Following the decisive victory in the 1991 Persian Gulf War, the reader may question the need for an analysis. Did the US not acquire air superiority within hours? Did the F-15C not amass a kill ratio of 34 to 0? Was the US not the envy of the military world as its F-15C units averaged 2.5 sorties per day with over 5,700 sorties?[4]

The answer is "yes" to all of the above. However, military planning is a dynamic endeavor. The French Maginot Line serves as a tribute to military leaders who do not comprehend the importance of changing doctrines. Since the Gulf War, the Air Force structure has downsized from 38.5 fighter wings to 20 fighter wings, 13 of which are active duty.[5] Current decisions will impact the Air Force well into the twenty-first century. The US must not plan for the last war.

The end of the Cold War resulted in a less defined threat. However, will the Russian threat remain dormant? The Communist Party gained a large block of congressional seats in recent elections. Reports from Moscow are replete with nationalist leaders calling for a return to the Soviet Union. Likewise, China continues to send mixed signals. Will China continue to grow economically using its increased economic resources to modernize its military? Recent developments between China and Taiwan illustrate the United States's friend-or-foe dilemma with China.

Uncertainties are not confined to the threats of potential adversaries. At the heart of military planning is how employment of exploding technologies will impact force structure. Is the world entering a revolution in military affairs (RMA) in which large force structures will give way to sophisticated technologies? Also, the proliferation of high technology in emerging nations could seriously compound US military planning. Thomas A. Keaney points out in the *Gulf War Air Power Survey Summary Report* that the mating of stealth and precision weapons was the beginning of the next RMA.[6] US doctrine must respond to this dynamic environment.

Without a doubt, decisions on these issues will affect the United States's role as a world power well into the next century. At the root of US military strategy is one principle that will never, be in question: the absolute necessity for American forces to command the airspace. This paper explores US air-to-air readiness, force structure, and modernization as it enters the twenty-first century.

Notes

[1] AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, vol. 2 (Washington, D.C.: GPO, 1992), 292.

[2] Ibid.

[3] Ibid.

[4] *Gulf War Air Power Survey*, vol. 5, *A Statistical Compendium and Chronology*, (Washington, D.C.: GPO, 1993), 276–77.

[5] "The US Air Force in Facts and Figures," *Air Force Magazine* 78, no. 5 (May 1995): 53.

[6] Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report* (Washington: GPO, 1993), 168.

Chapter 2

Eagle Readiness: The Good

Near-term readiness refers to the ability of US forces to perform their assigned tasks right now, if called upon to do so. This type of readiness requires constant attention and to a larger extent, robust operation, and maintenance planning.

—Secretary of Defense William Perry

Introduction

Of the three pillars in military planning, modernization and force structure share a long-range perspective, while readiness maintains a near-term focus. Dr William Perry defines readiness as the ability to mobilize, execute, and sustain forces when requested.[1] This chapter examines the readiness issues of the Air Force's front-line fighter, the F-15C, and its air superiority mission.

The American public neglected the US military both financially and emotionally following Vietnam. The term "hollow force" was coined to characterize the readiness posture of the US military. The hollow forces were plagued with 60 percent mission capable rates, technician training shortfalls, and a lack of spare parts. The hollow force failed the Perry test: it couldn't mobilize, execute, or sustain.

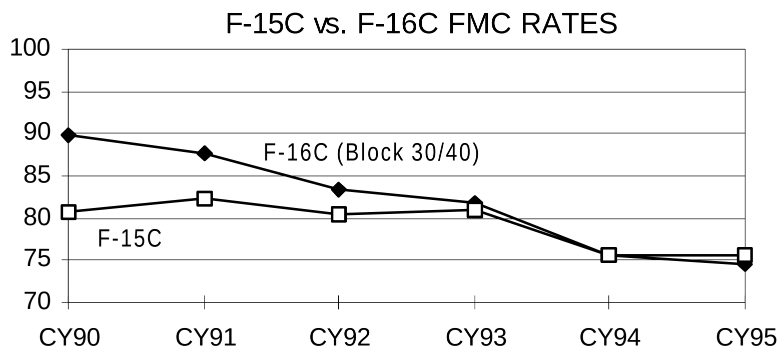
Today, several conditions indicate the US may be heading towards another hollow force as we make tough decisions to reduce the military budgets. Since 1992, the F-15C fully-mission-capable (FMC) rate has dropped from 83 percent to 76.8 percent[2] (See fig. 2-1). Likewise, the F-15C break rate has increased to 18 percent during the same three-year period.[3] Noted lecturer, Franklin C. Spinney stated, "This is the same decision-making strategy that created the cost-spiral and hollow military of the 1970s."[4] The effects of a hollow air force in the twenty-first century will be serious.

This chapter analyzes the readiness posture of the F-15C aircraft. Following a review of the literature on readiness, there is an analysis of the primary factors affecting readiness. This chapter concludes with recommendations that enhance F-15C employability into the next century.

Literature Search

The current state of F-15C readiness is a qualified *good—a good* with trouble on the horizon, a *good* compared to a *bad* force structure and an *ugly* modernization. F-15C equipped units can mobilize, engage the enemy, and achieve air superiority. However, declining FMC rates, increased breakrates, and increased cannibalization rates are warning indicators of low readiness. The question is: How bad is it, and what can the US do to avert another hollow force?

Although Mission Capability (MC) rates have decreased slightly, FMC rates have decreased dramatically in the past three years (See fig. 2-1).



Source: Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 1990-95 F-15C and F-16 maintenance statistics, 12 Dec 1995.

Figure 2-1. F-15C vs. F-16C FMC Rates

Note the significant decrease in the F-15C and F-16 FMC rates over a period of five years. These indicators within the fighter community point to possible readiness problems (See appendix A).

Key military leaders agree—readiness is an issue. General John Nowak, Deputy Chief of Staff of Logistics, Headquarters, United States Air Force (USAF), identified spare-part shortages as a readiness problem. Gen Nowak states:

> In addition, the readiness spare package fill levels will remain lower than desired and cannibalization rates will probably drift over the next few years . . . [units] report a decline in readiness spares on hand to fly initial war surge.[5]

Col Looney, former wing commander of the 33TFW, appeared before Congress in April, 1994, and supported Gen Nowak's views on readiness. Col Looney reported having to lower the combat capability rating in two of his three fighter squadrons because of a shortage of engine modules.[6]

The growing controversy over unit readiness in 1994 prompted then Secretary of Defense, Les Aspin, to create a blue-ribbon panel headed by retired Army General

Edward Meyer. General Meyer's panel reported that although readiness levels were generally acceptable, there were hollow-force indicators. Gen Meyer stated, "There are sufficient identifiers and we had better pay attention to them."[7] The panel voiced two primary concerns: first, a growing number of aircraft maintenance indicators to include serious F100 engine backlogs in the depots; second, the increased operations tempo due to the support of humanitarian contingencies.[8]

Senator John McCain (R-Arizona), a highly decorated Naval aviator, assessed the situation in a December 1994 Senate Armed Services Committee hearing.

> I believe we are now seeing the beginning of a new hollow force . . . they [armed services] are maintaining current readiness at the expense of future, long-term readiness. The services are spending their dollars to keep equipment operating in the high-tempo environment of expanding nontraditional missions, rather than developing and buying modern equipment.[9]

Read between the lines. Nontraditional missions and long-term readiness? Senator McCain stated the 1994 defense strategy was to fund near-term readiness in nontraditional missions at the expense of upgrading force structure. Simply put, Somalia for spare parts and Haiti for training sorties. But, what is the effect of such a strategy on daily operations?

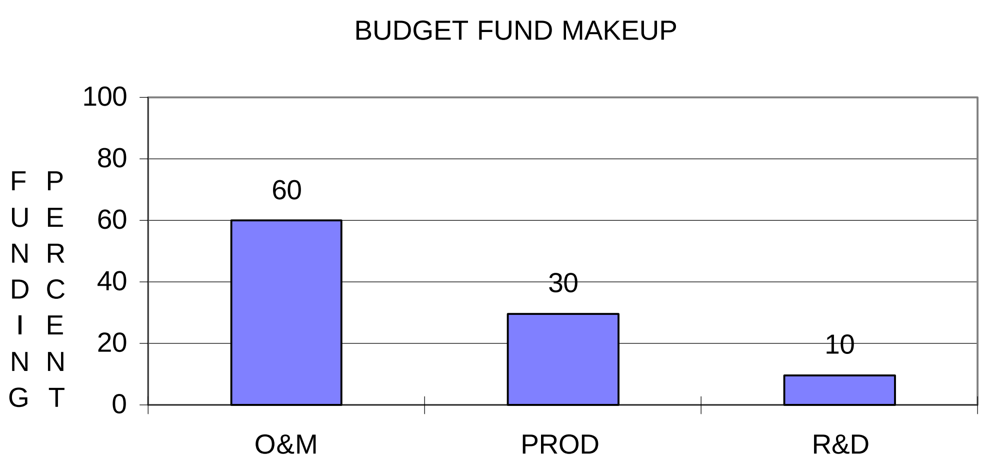
Operations Tempo and the Operations and Maintenance Budget

Operations tempo is a key factor in the readiness equation. Evidence supports Senator McCain's comments that readiness has suffered because the focus has shifted away from traditional military missions. Since the end of the Cold War, the US has provided forces for several major contingencies. For example, the US completed three times the sorties in Southern Watch as it did in the Gulf War; and flew an additional

18,000 sorties in Bosnia. This increased operations tempo affected the force directly and indirectly.

Secretary of Defense Perry's annual report specifically addresses the effect recent contingency operations have had on military Operations and Maintenance (O&M) budgets and near-term readiness. The report identifies a total of $2.6 billion earmarked for contingencies in 1994.[10] Obviously, the unplanned loss of $2.6 billion in O&M funding impacts daily operations. President Clinton earmarked an additional $25 billion for replacement costs over the next six years, but over half of the $25 billion will not be available until after 2000.[11] This has severely strained both training and maintenance operations.

The readiness of the Air Force and, more specifically, the F-15C aircraft, are directly affected by the operations tempo of recent years. The O&M budget funds the repair and procurement of vital parts that comprise the F-15C subsystems (See fig. 2-2).



Source: Ben Hollingsworth, Financial Manager, WR-ALC/LFCF, memorandum for record, 13 Dec 1995.

Figure 2-2. Budget Fund Makeup

An interview with Ben Hollingsworth, financial manager in the F-15C Program Office at Warner-Robins Air Force Base (AFB), highlights the importance of the O&M budget in daily flying operations. Hollingsworth identified three important O&M funding elements of the F-15C repair cycle. First, Repairable Support Division (RSD) finances repair of depot level systems and modules. Second, RSD procurement dollars finance acquisition of spare parts. Third, System Support Division (SSD) is used for consumable piece-parts.[12] These three funds are the foundation of the depot level repair and parts support system.

Currently, Hollingsworth feels all three are funded adequately. However, the funding from 1992 to 1994 was inadequate. During these years the combined shortfall for RSD funding was almost 60 percent.[13] The major shortfalls were in RSD repair accounts and SSD accounts. This information supports Senator McCain's statement that funding was transferred from the support accounts to the contingency accounts.

Since 1994, DOD leaders have personally led the charge for better O&M funds management. Secretary Widnall stated, "Stability in our O&M budget is key to maintaining Air Force readiness, and that stability depends on timely funding for contingency operations."[14] Likewise, General Shalikashvili emphasized the importance of O&M funding. He stated that although the force structure has been downsized, overall O&M funding is up 5.6 percent in the 1996 budget.

General Shalikashvili mentioned a similar relationship in the repair process where aircraft force structure has been reduced about 35 percent, but depot repair funding has increased by 20 percent.[15] By 1995, the O&M budget was funded 117.1 percent.[16] This increase is sufficient to overcome the 19.9 percent reduction in 1994. However, as the F-15C ages more O&M funds are required to fix the aircraft.[17]

Obsolescence and the Eroding Industrial Defense Base

Obsolescence is a major source of readiness degradation. Jerry Gibbs, a recognized industry expert on obsolescence, defines it as the lack of the industrial base to supply the Air Force with sufficient replacement parts.[18] How bad is it? In 1987 there were 201 F-15C part shortfalls, in 1994 there were 2,683.[19]

Avionics subsystems are the main source of obsolescence.[20] Only four industrial plants remain open for avionics and flight controls. The dramatic drop in manufacturing capability for the five subsystems will have a severe impact on the readiness of the F-15C. Jerry Gibbs predicted that by 2001 almost 50 percent of F-15C radar systems will be obsolete.[21] (See table 2-1).

Table 2-1. F-15C Industrial Base Problems

Subsystems	Revenue Decrease	Plants Remaining
1. Avionics	-20.0 %	4
2. Navigation/Guidance	-45.3 %	13
3. Fuselage (Airframe)	-38.0 %	8
4. Propulsion	-8.1 %	6
5. Flight Controls	-2.6 %	4

Source: Briefing, WR-ALC/LFE, subject: Avionics Obsolete Parts, 4 Dec 1995.

The problem is widespread. The main cause is the subcontractor supporting the prime contractors. A RAND study surveyed 181 companies and discovered alarming indicators of economic turmoil.[22] The study revealed fewer than 300 subcontractors supporting eight major defense programs. With 194 subcontractors supporting the largest contractor, only 68 subcontractors remain to support the other seven programs.[23] There is a serious shortage of subcontractors.

Migration of microelectronics subcontractors from the defense sector is the primary reason for the shortage. John Kanz, of the University of Calgary, estimates the distribution of microelectronics firms is 65 percent focused on the personal computer market, 12 percent on the automobile industry, and only two percent on DOD.[24] This is in direct contrast to the 1980s when the defense industry dominated the microelectronics business. Lamar Williamson, Chief of Engineering Division at Warner-Robins Air Logistics Center (WR-ALC), stated that "subcontractors producing software and integrated circuits are particularly vulnerable to rapid technology change."[25] Integrated circuits have a life cycle of six years, while the F-15C's average age is approaching 15 years. It is extremely difficult to compute long-term maintenance strategies if the technology is obsolete in six years.

Williamson identified three trends in the electronics industrial base. First, an inverse relationship exists between extending aircraft service limits and the decreasing life of the modern electronic and computer products.[26] As defense budgets get smaller, existing aircraft are extended beyond their original service limits to maintain force structures. Conversely, the life of the electronic product is getting shorter due to technology growths. These opposing forces are a root cause of obsolescence.

Second, the highly specialized and regulated DOD market does not provide the market base for companies to survive. With sharp drops in force structure, the number of weapon systems has decreased dramatically.[27] Companies cannot survive on such small market shares.

Finally, during the Cold War era, the Defense Department dominated the industrial market. Since the end of the Cold War, the free market system has replaced Defense Department contracts. The market economy is now the force in the electronics industry, not large, government subsidized contracts.[28] Rick Cassidy, Vice President of General Motors, Military-Space Division, recently supported this when he stated, "Microcircuit sources haven't gone away—they have reallocated their resources to what market demands. There are more manufacturers today than in 1980."[29] If the shift in the defense industry is affecting readiness in 1994 with 15 year old F-15Cs, how can the Air Force manage these problems in 2010 with much older aircraft? The Air Force appears to be aggressively working the problem.

Interviews with Jerry Vaughn, Avionics Manager from WR-ALC, indicate the F-15 System Program Office has a plan. Although not economical, Vaughn prefers a one-time buy which ensures supply throughout the life of the system.[30] He also suggests clones and reengineered parts manufactured as substitutes for original components. Finally, Vaughn identifies *sunset* manufacturers as a new type of vendor. *Sunset* manufacturers produce obsolete parts original manufacturers have discarded. These contractors have emerged due to the increased obsolescence problem.

As a stop-gap solution to the obsolescence problem, the depot has signed a support contract with Unohali Corporation. This firm provides electronic parts obsolescence management. Jerry Gibbs, a manager for Unohali, says his company conducts surveys of suppliers for F-15C avionics components.[31] The surveys forecast potential part shortages, alerting the depot to future shortfalls.[32] Companies emerging as obsolescence managers to fill specialized markets illustrate the obsolescence problem.

As the rate of technology accelerates, the problem of obsolescence will require greater management attention. However, innovative approaches such as those demonstrated by Vaughn and Gibbs reduce the effects of the obsolescence problem. Yet, innovative approaches are not limited to obsolescence.

The Logistic Repair and Supply Cycle

The logistic repair and supply cycle is a critical feature in the investigation of F-15C readiness. The most advanced fighters are useless if they do not possess the logistic system to sustain their operations. History is full of examples of powerful armies who were vanquished for the lack of sustained logistics support: Napoleon in Russia, Field Marshall Rommel in North Africa, and Field Marshall Paulus in Russia.

Today's F-15Cs share a similar dependency on logistics. Unfortunately, the current system is inefficient and desperately requires a facelift. A recent RAND report indicates the current DOD logistic system has "relied on a mass-logistics paradigm." [33]

The bulk logistic moving system used today can be traced back to the grandiose logistic buildups of WWII campaigns such as the Normandy invasion.[34] General Yates, past commander of Air Force Material Command, stated:

> We used to say, extra inventory, extra aircraft and we'll be safe. We can't afford that any longer. We've got to take some risk and focus on just-in-time inventory rather than just-in-case inventory.[35]

However, the current logistics system is still geared for large bulk shipments to halt a Soviet advance through the Fulda Gap.[36] Although effective in historical military contingencies, it is not efficient with modern technologies. A 1994 RAND study showed average parts-on-order time of 30 days, with some exceeding 100 days.[37]

The Air Force is trying innovative approaches to solve these problems.[38] There are two major programs to improve readiness: the realignment of the configuration management from WR-ALC to the Defense Logistics Agency (DLA) and Lean Logistics.

The transfer of configuration management from the depot to DLA created some initial problems. The DLA organization was accustomed to bulk procurements. DLA did not understand the importance of individual parts and their effect on the mission status of individual F-15Cs.[39] The transfer of responsibility to DLA created a dual management system that obscured the unity of command concept with the depot personnel backing up the DLA ordering process.[40] A RAND study determined "DLA's use of fill rates to metric customer satisfaction resulted in DLA managers *gaming the system* by stressing high volume, low dollar items in place of high dollar, low volume, like aircraft parts" (Emphasis added).[41] Fortunately, DLA confirms the process is improving as management transfer matures.[42] The results are not as favorable with Lean Logistics.

The Lean Logistics program is a reengineering distribution process like those completed successfully in the commercial transportation industry. It is based on three fundamental concepts: development of commercial-like point-to-point transportation systems; reductions in repair cycle times associated with the two-level maintenance concept; and dramatic reductions in inventories of supplies and equipment using just-in-time logistics.[43]

A 1994 RAND study determined "The commercial industry recognized great improvements in process measurements and most importantly customer satisfaction through reorganization".[44] Another RAND study compared DOD and commercial ordering and shipping times[45] (See table 2-2).

Table 2-2. DOD and Commercial Ordering and Shipping Times

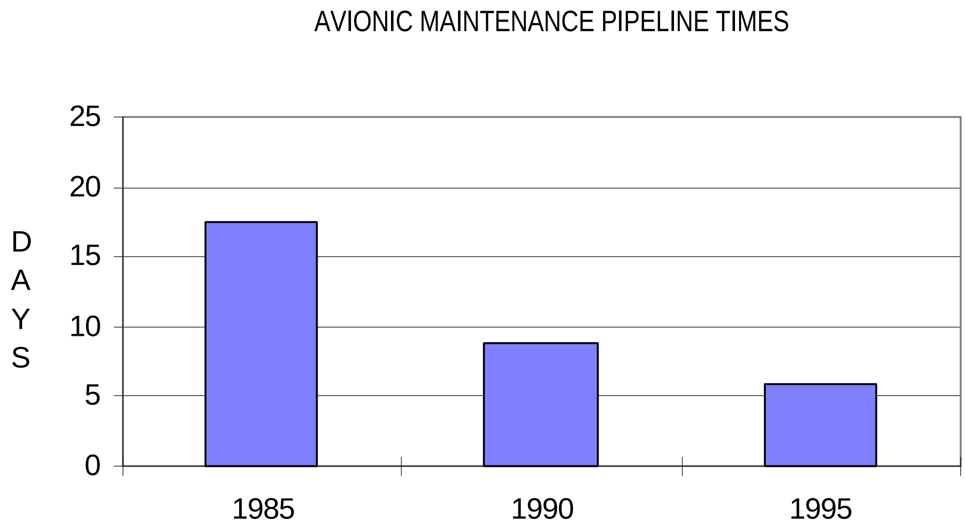
Process	DOD	Commercial	Commercial
1. Distribution	26 Days	1 Day (Motorola)	3 Day (Boeing)
2. Repair (Electronic)	8-35 Days	1 Day (Compaq)	10 Days (Boeing)
3. Repair (Mechanical)	40-144 Days	3 Days (Cummins)	14 Days (Boeing)

Source: Kenneth Girardini, et al., "Improving DOD Logistics," RAND Report (Santa Monica, CA: RAND Corporation, 1995), vi.

A strong case can be made for change in the military transportation and repair system. Preliminary data supports point-to-point transportation innovations. However, the results are mixed for the two-level maintenance portion of Lean Logistics.

The RAND Corporation conducted an evaluation of the two-level maintenance system. The study indicated savings in the two-level maintenance system were greatest when managers concentrated efforts on reducing transportation and base processing times. The two-level concepts saved $96.9 million. Savings resulted from reducing transportation time using commercial express delivery service and shortened base processing times.[46]

Although the programs are still developing, the two-level avionics program looks very promising. Secretary Widnall wrote in a recent article that the avionics repair pipeline times have been reduced by 66 percent (See fig. 2-3).[47]



Source: Sheila E. Widnall, "Widnall Assesses the Force," *Air Force Magazine* 78, no. 4 (Apr 1995): 33.

Figure 2-3. Avionic Maintenance Pipeline Times

However, reported savings should be viewed with caution. Air Mobility Command (AMC) and Air Combat Command (ACC) tests confirm preliminary field data which show significant savings in the avionics two-level.[48] Yet, serious doubts exist in the propulsion two-level program. Long delays in the repair cycle have seriously affected readiness at several F-15C bases. Unofficially, depot officials confirmed the two-level program for engines will stop in the near future.[49]

While the readiness posture is favorable for the near-term, several indicators are troubling. The remainder of this chapter will analyze near-term readiness and evaluate current readiness indicators. The analysis suggests the US may be in the embryonic stages of a hollow force.

Methodology for Readiness

Data Collection Method

The authors collected historical maintenance data from three sources. First, WR-ALC provided an F-15C database that possessed the maintenance statistics from 1990 to 1995 for all F-15C aircraft. Mr. Jeff Hill, data manager at WR-ALC, collected data from the Tactical Interim Cams and Remis Reporting System (TICARRS) maintenance database.[50] Second, Dynamics Research Corporation (DRC) prepared a similar database for approximately 300 F-15Cs assigned to operational units.[51] The DRC database also provided F-16 data on all Block 30/40/50 aircraft. In addition, the Air Force Logistics Management Agency provided quarterly maintenance reports from the three major commands. This data was similar to DRC and TICARRS, but specific to the individual major commands.

In addition to maintenance data, WR-ALC provided a thorough budget history of the F-15C's RSD buy, RSD repair, and SSD accounts. The funding data was used in conjunction with the maintenance data to identify any correlation between the two funds. The raw data was used to develop graphs tailored to this specific investigation.

Statistical Trend Analysis

The statistical analysis process conditioned the maintenance data. Trend analysis identified the key factors influencing the FMC rate, the overall best indicator of readiness. This study centered around the sharp decline in FMC rates since 1992. Three potential causes were analyzed: aging of the aircraft, spare parts availability, and operations tempo related to O&M funding.

This study investigates the aging aircraft theory using three methods. First, data from older F-15C aircraft units was compared with newer units. Second, statistics comparing aging between the F-15 and the F-16 were analyzed. Finally, the F-15C breakrate indicators were studied for possible trends.

Regression Model Analysis

The analysis used data from both WR-ALC and DRC in the Interactive Statistical Program (ISP) to perform multiple regression analysis.[52] This method used FMC as the dependent variable and the factors identified in the statistical analysis as independent variables. The model was first verified for accuracy using standard practices with both a *p* test and a *t* test.

The regression analysis yielded two products that were used for further analysis. First, a regression coefficient table was used to determine the interrelationships between the variables in both magnitude and direction. Second, a prediction equation was generated and verified. Then, it was compared to the actual FMC trend and an evaluation was conducted to determine possible effects of various fluctuations in the independent variables. The results of three hypothetical scenarios (best case, worst case, most-likely case) were then graphed and analyzed.

Assumptions

1. The Mission Capable MC rate is a function of the subjectivity of the unit reporting. The FMC rate represents a more accurate test of readiness then the MC rate.
2. The lag between increased RSD funding and actual field improvements is two years. Due to the lead time in contractual and production times, the effects of the increased funding lags behind the allocation dates.
3. The transfer of O&M funds during the 1992 to 1994 contingency operations was taken from accounts which affect base or depot level operations.

4. The effect of the selected maintenance indicators include the effect on unit training, leadership, organization, and experience levels. The local makeup of the unit is not systemic to the aircraft analysis.

Statistical Readiness Analysis

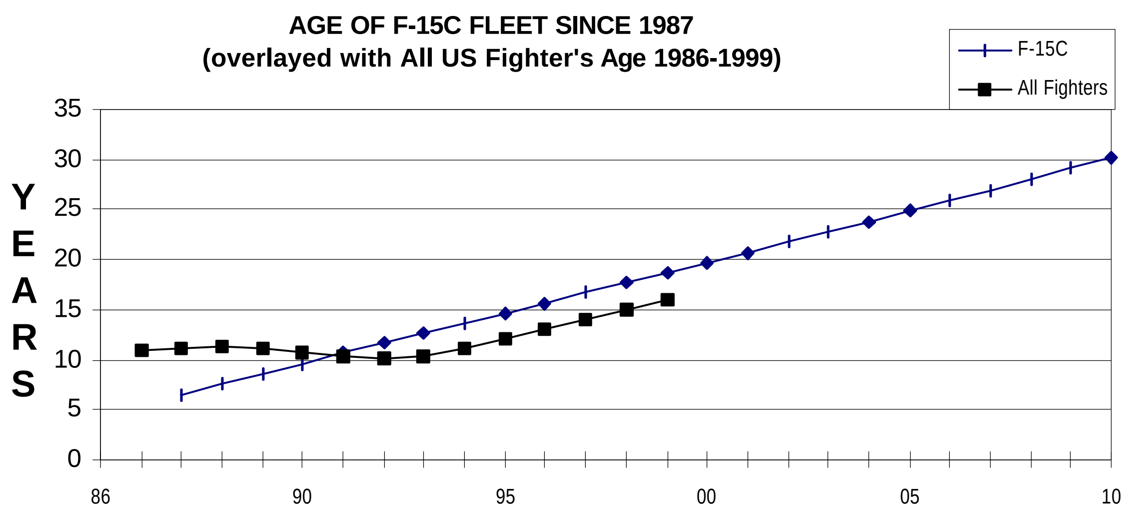
This section uses statistical analysis techniques to investigate three areas: aging aircraft effects, supply cycle and part availability, and funding shortfalls. The analysis will determine the main contributing sources influencing F-15C readiness and identify if the sources are systemic to the aircraft. From this analysis, two critical questions can be answered. Will F-15C readiness continue to decline and curtail plans to extend F-15C service life limits to 2014? How can resources be used to manage the F-15C into the twenty-first century? Both questions are a function of the aircraft's age.

Aging Aircraft Syndrome: Is it a Readiness Factor?

The aging aircraft syndrome means that the mission capability of an aircraft follows a reverse-bucket shape. In the earlier years of production, mission capability is lower due to the new equipment.[53] After the "bugs are worked out" and the maintainers gain experience, the mission capability of the aircraft stabilizes at a higher level. The higher level holds somewhat constant until the age of both the airframe and major subsystems approach their service limits.

The Air Force measures the F-15C service life limits using flying hours. Originally, the design limit of the F-15C was 4,000 hours. In 1995, Wright Laboratory structurally tested the F-15C airframe to 18,000 hours without any significant cracks.[54] Based on the success of the testing, sources predict the Air Force will extend the original service life from 4,000 hours to at least 8,000 hours.[55] With today's average fleet age of 3,400 hours, an increase to 8,000 hours would extend the F-15C to at least 2014.[56]

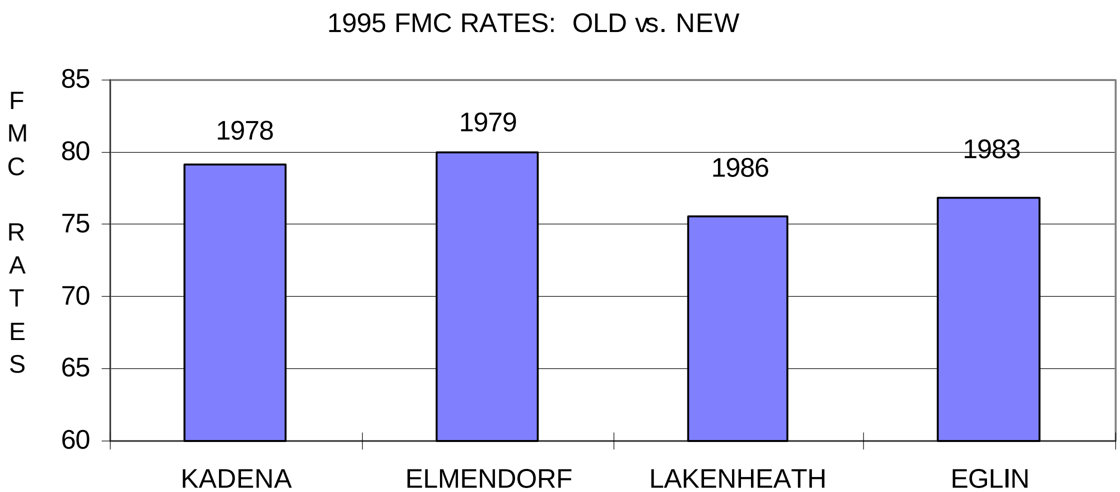
In 1996, 32 percent of the F-15Cs are 9 to 12 years old; 51 percent are 12 to 15 years old; and 17 percent are aged between 15 and 18 years.[57] The oldest F-15Cs were produced in 1978, the newest in 1986. An extension of the F-15C to 2014 will result in 36 year old airframes (See appendix D). As can be seen, how well the airframe ages is an important readiness factor (See fig. 2-4).



Source: Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 1990-95 F-15C and F-16 maintenance statistics, 12 Dec 1995.

Figure 2-4. Age of F-15C Fleet Since 1987

With production of the F-15C stopping in 1986, each year projects a linear aging fleet. Hence, by 2010 the fleet will be approximately 30 years old. What compounds the aging problem is that the F-15C is just part of an entire tactical fighter force that is also aging. The overall tactical fighter fleet follows a similar trend. Today, the average age of all fighters is 12 years. The average age of these fighters will be 18 years by 2010. At this point, nearly 10 percent of the tactical fighter force will exceed their designed retirement age.[58] The simultaneous aging of both the F-15C and F-16 could lead to serious problems. The tactical force is already stressing the parts and maintenance cycle due to aging. Any attempt to replace the F-15C and F-16 simultaneously would also create a serious draw on limited acquisition funding. Does an aging F-15C fleet have an impact on readiness? Four different F-15C bases where analyzed (See fig. 2-5).



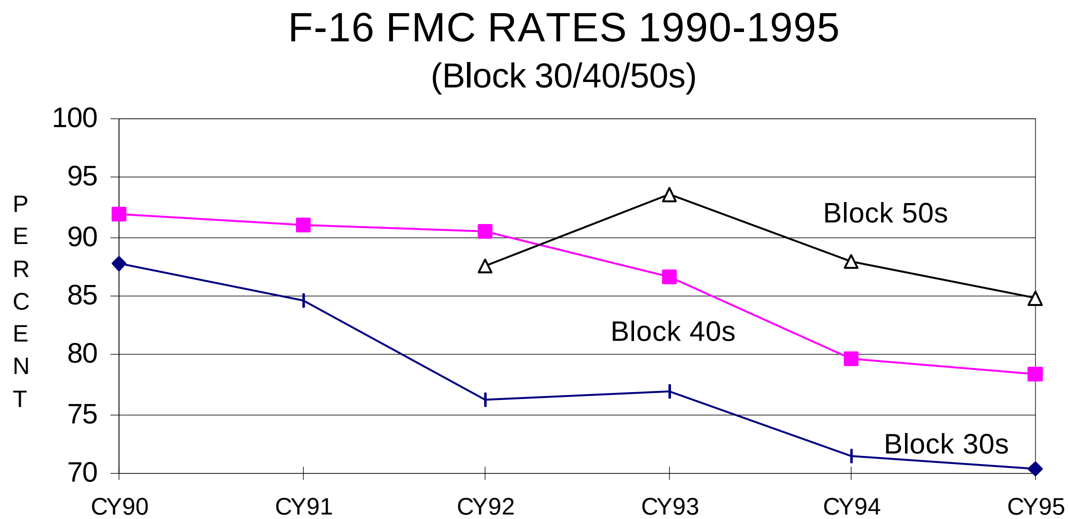
Source: "The CBO's Air Force," *Air Force Magazine* 78, no. 3 (Mar 1995): 30.

Figure 2-5. 1995 FMC Rates: Old vs. New

The relationship is directly reverse what we would expect. Kadena and Elmendorf, the two oldest F-15C units, possess the highest annual FMC rates for 1995. On the other hand, Lakenheath has the newest models with only a 75.6 FMC rate. Likewise, Eglin has 1983 models and possesses a 76.9 FMC rate.

It appears the FMC statistics do not support the aging airframe theory. However, other factors are at work. For example, the Lakenheath and Eglin squadrons maintained a high operations tempo in 1993 and 1994 with extended deployments while Kadena and Elmendorf stayed home.[59] Also, both Eglin and Lakenheath possess the F100-PW-220 engine, while Elmendorf and Kadena possess the F100-PW-100 engine. Although the -100 has a higher unscheduled maintenance rate than the -220, the -220 engine has had severe parts shortages in the last two years.[60] Hence, the data does not support aging as a major contributor to a decline in mission capability.

Although this paper addresses the F-15C as the primary air-to-air fighter, a contrast analysis of the F-16 provides an additional perspective into the aircraft aging process (See fig. 2-6).



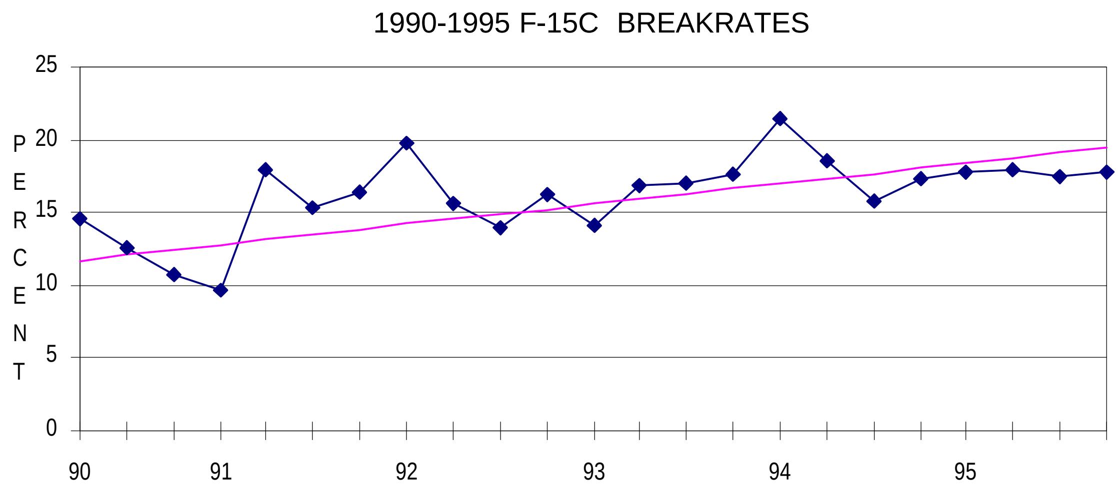
Source: Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 1990-95 F-15C and F-16 maintenance statistics, 12 Dec 1995.

Figure 2-6. F-16 FMC Rates 1990-1995

There are two very important observations. First, there is a correlation with aging. As aircraft get older they decline in reliability. Both the Block 30s and the Block 40s decline at a parallel rate. Second, and more importantly, the trends follow a similar pattern to the F-15Cs. Three different weapon systems, yet FMC rates in all three drop dramatically from 1992 to 1995. From an aging aircraft perspective this should not happen. Even the new Block 50s have dropped almost 10 percent, from 93.6 percent in 1993 to 84.9

percent in 1995. Factors other than aging are influencing the mission capabilities of both the F-16 and F-15.

Another key trend that disproves the aging aircraft theory is the breakrate trend of the F-15C. Breakrate measures the number of code three system reports following each sortie. A code three report identifies a major system failure which renders that aircraft as NMC (See fig. 2-7).



Source: Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 1990-95 F-15C and F-16 maintenance statistics, 12 Dec 1995.

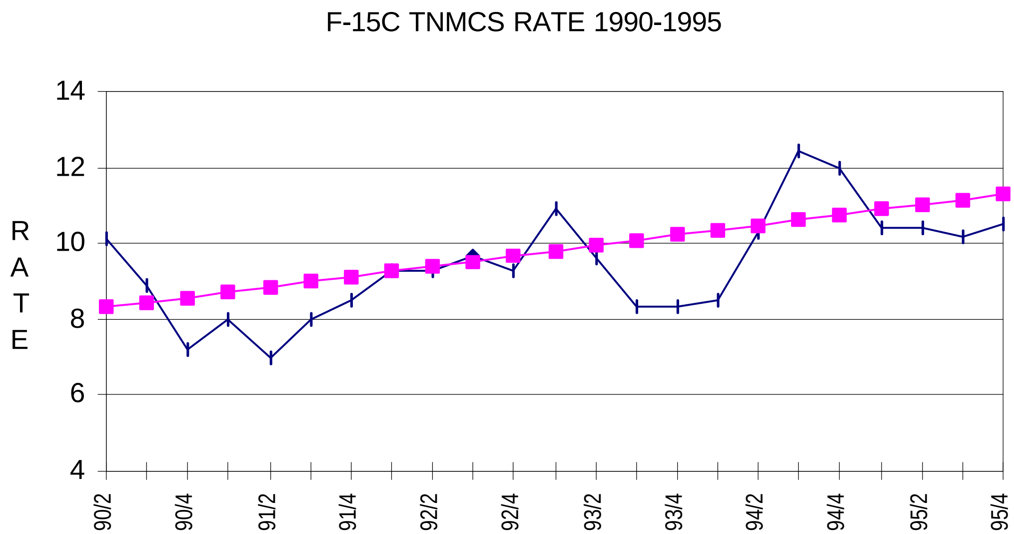
Figure 2-7. 1990-1995 F-15C Breakrates

The breakrate does not indicate a systemic increase in code threes. The trend is positive. But, the trend is relatively flat from 1992 forward. Local preventive maintenance programs and a robust subsystem modernization program can manage the breakrate problem. The breakrate data is directly linked to aircraft aging. Close scrutiny of this indicator will flag long-term aging problems.

In summary, the analysis does not support a theory that the F-15 is aging beyond normal levels. Aging aircraft require additional maintenance and sustainment efforts. The system is not age-limited if the proper maintenance upgrades are accomplished. Based on analysis from both F-15Cs and F-16s, other factors have accelerated the deterioration of the mission capability rates.[61] One of these factors is funding of spare parts.

Spare Parts And The Supply Cycle: How Bad Is It?

The analysis examined three parameters relating to the parts problem: total non-mission capable supply (TNMCS) rates; cannibalization rates; and repair cycle times. The TNMCS rate represents a history of supply requisitions (See fig. 2-8).



Source: Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 1990-95 F-15C and F-16 maintenance statistics, 12 Dec 1995.

Figure 2-8. F-15C TNMCS Rate 1990-1995

This trend depicts trouble on the horizon. Again, like FMC rates, 1992 to 1994 were pivotal years. The dramatic increase in TNMCS from 7.9 percent in 1991 to 10.8 percent in 1993 explains a similar decline in FMC rate during the same period.

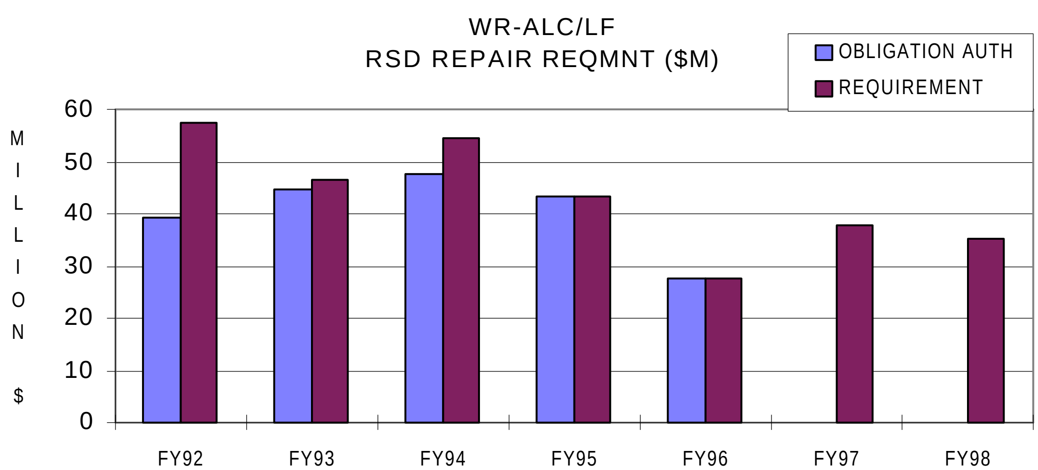
The analysis revealed a key factor that influenced the increased TNMCS rates: a large mismatch between required and actual depot funding from 1992 to 1994.[62] Funding was reduced below required levels in four major funding categories:

1. RSD Funds for Parts Procurement.
2. RSD Funds for Depot Level Repairs.
3. SSD Funds for Expendable.
4. O&M Funds for Daily Operations.

The universal drop in all funding categories coupled with an increased operations tempo is at the very root of the parts shortages from 1992 through 1995. A review of each funding source provides an excellent case for placing the readiness concerns of 1996 on the funding limitations of 1992 to 1994—not aging aircraft or two-level maintenance.

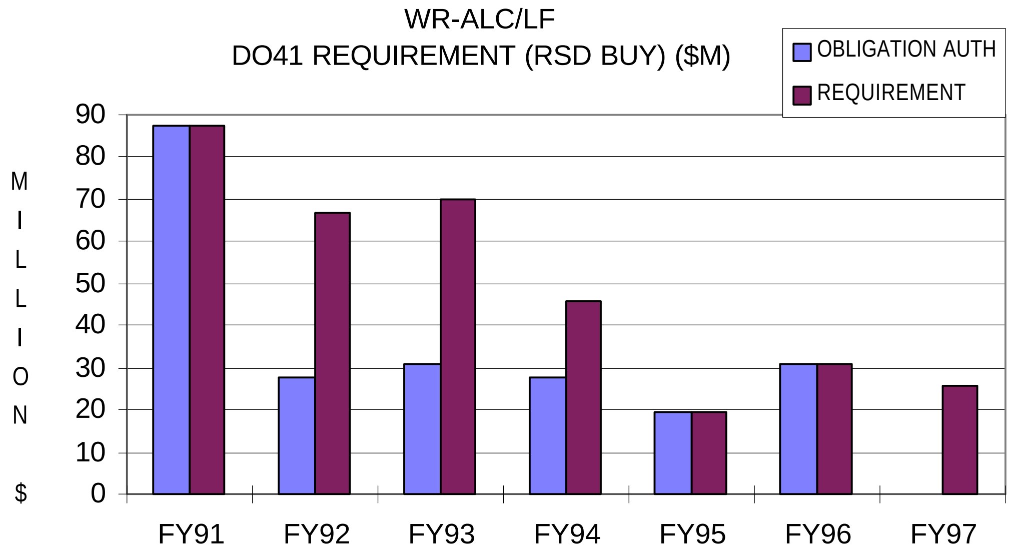
RSD Funding: The Root Of The FMC Problem

RSD funding provides the required funds for depot repairs and for new or overhauled components.[63] There was a shortfall in these funds from 1992 to 1994 (See fig. 2-9 and fig. 2-10).



Source: Ben Hollingsworth, Financial Manager, WR-ALC/LFCF, memorandum for record, 13 Dec 1995.

Figure 2-9. WR-ALC/LF RSD Repair Requirement



Source: Ben Hollingsworth, Financial Manager, WR-ALC/LFCF, memorandum for record, 13 Dec 1995.

Figure 2-10. WR-ALC/LF DO41 Requirement (RSD Buy)

This shortfall resulted in the inability to replace deficient line replaceable units (LRU) or shop repairable units (SRU) (See table 2-3).

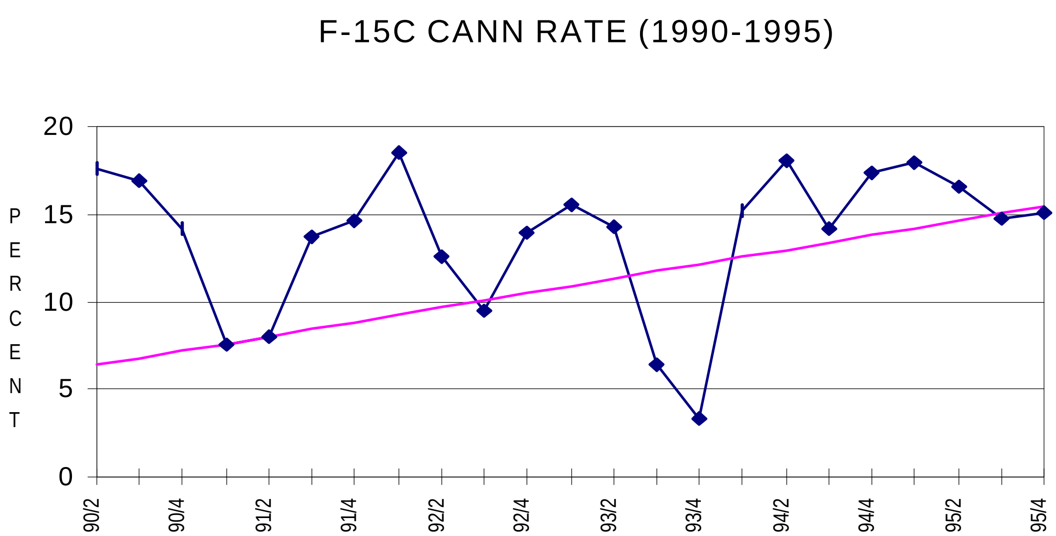
Table 2-3. RSD Buy and Repair

Fund Type	FY92	FY93	FY94	FY95	FY96
RSD Buy %	-57.9	-57.1	-33.8	0.0	0.0
RSD Repair %	-29.1	-3.3	-11.9	0.0	0.0

Source: Ben Hollingsworth, Financial Manager, WR-ALC/LFCF, memorandum for record, 13 Dec 1995.

Drastic shortfalls severely affected the ability to repair bad components and the ability to buy new components: especially, the RSD buy shortfalls. Fifty-seven percent shortfalls in FY 1992 and FY 1993 placed the LRU/SRU supply inventory into serious disarray. Consequently, the supply system was unable to meet the LRU and SRU demands at the base level. This forced maintainers to use cannibalization techniques to keep the F-15C flying.

Cannibalization is the maintenance action of removing a good part from one aircraft to fix another aircraft. Maintainers consider cannibalization actions as a last resort because they double the workload. It is an inefficient maintenance action that is completed when the supply system cannot provide the parts required. Sixty percent shortfalls in RSD new-buy funding in FY 1992 to 1994 planted the seeds of the increased workload. A review of past cannibalization rates illustrate how the RSD and SSD shortfalls affected F-15C maintenance units. Using the trend-rate line, cannibalization rates increased by almost 50 percent from 1990 to 1995. The increase in cannibalization rates in the last five years indicates an increased maintenance tempo to solve spare part shortfalls (See fig. 2-11). The F-15C engine is one of the subsystems most often cannibalized.

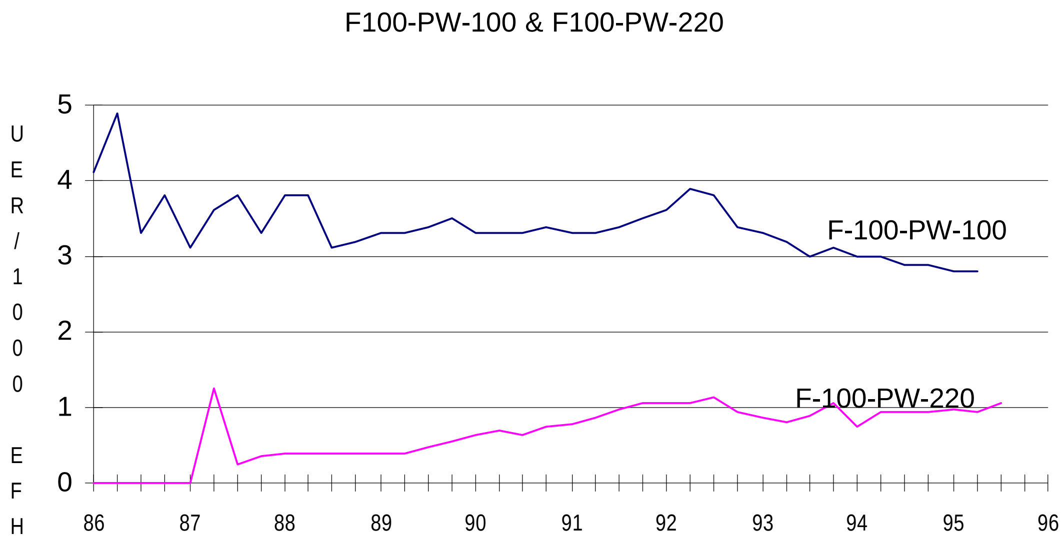


Source: Jeff Hill, TICARRS Database Manager, WR-ALC/LF, 1990-95 F-15C maintenance statistics, 6 Dec 1995.

Figure 2-11. F-15C Cannibalization Rate (1990-1995)

Two engine models propel the F-15C: the F100-PW-100 in the aircraft produced before 1983, and the F100-PW-220 in aircraft produced after 1983. Three observations were discovered during the engine RSD funding analysis: first, the older -100s have a much higher breakrate than the -220s; second, although the -220 has higher reliability, it has a shortfall of RSD funded modules; and last, both engines possess very high scheduled fan inspection requirements.[64]

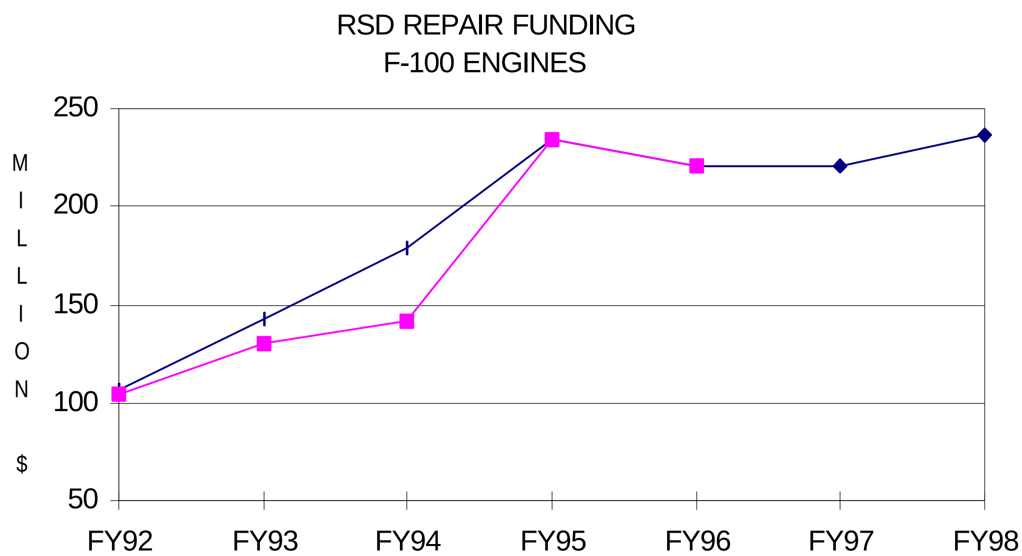
The -100 engine has a 60 percent higher unscheduled engine removal (UER) rate than the much more reliable -220[65] (See fig. 2-12).



Source: Fred Mullis, Pratt & Whitney Customer Service Rep, P&W SA-ALC, USAFE F100 Overview: Mar 94-Mar 95 (DO42), 12 Dec 1995.

Figure 2-12. F100-PW-100 and -220 UER Rate

While the -220 enjoys a much lower UER rate, it also suffers from a serious shortage of modular parts due to RSD shortfalls and RSD repair funding at the depot level from FY 1993 to FY 1994 (See fig. 2-13).



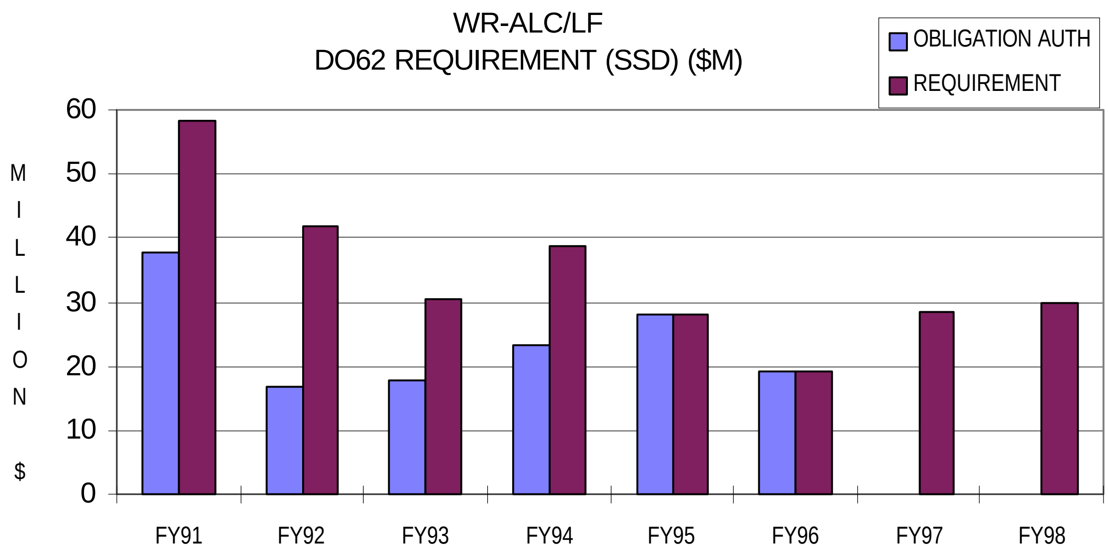
Source: Debbie Delano, F100 Turbine Manager, SA-ALC/LP, telephone interview with author, 25 Mar 1996.

Figure 2-13. RSD Repair Funding, F-100 Engines

As in WR-ALC aircraft funding, the San Antonio Air Logistics Center (SA-ALC) engine funding had similar shortfalls of nine percent in FY 1993 and 21 percent in FY 1994. Like airframe funding, the engine funding was raised to 100 percent starting in 1994, but units still suffered from the lag between funding and production.[66]

SSD Funding: Big Dollars For Little Parts

Likewise, the SSD funding saw dramatic funding cuts during the same period. SSD funds purchase what maintainers refer to as piece-parts. These are small parts that are attached to RSD components. Although far less expensive than RSD components, they are still vital to the mission capability of the F-15C. For example, an F-15C costs $35 million. However, it isn't FMC unless the multi-purpose color display (MPCD) has the $6.10 attachment on the control panel. Currently, MPCDs are in critically short supply because of SSD piece-part funded attachments on the panel.[67] The SSD and RSD shortfalls are similar (See fig. 2-14).



Source: Ben Hollingsworth, Financial Manager, WR-ALC/LFCF, telephone interview with author.

Figure 2-14. WR-ALC/LF DO62 Requirement (SSD)

SSD shortfalls were 60 percent from FY 1992 through FY 1994. Although SSD and RSD were funded 100 percent in FY 1995 and FY 1996, the problem will continue for at least another 24 months.[68] This is due to the long lead time from funding authorization to actually placing the part in the supply bin. Hopefully, continued 100 percent funding of RSD and SSD will replenish the LRU inventories.

O&M Funding: Money for Daily Operations

O&M funding follows the same pattern as RSD and SSD funding. The O&M budget was reduced 25 percent in FY 1992 and FY 1993. Granted, a 25 percent reduction may appear reasonable with the force structure drawdowns of FY 1992 to FY 1994. However, the 25 percent reduction in O&M funding in FY 1992 to FY 1993 did not correspond to a reduction in F-15C operations tempo. In fact, the F-15C operations tempo actually *increased* by 8.7 percent.

Two major events occurred simultaneously that directly influenced O&M funding. First, the USAF supported the Kurds in Northern Iraq and the Shiites in Southern Iraq following the 1991 Gulf War. The F-15C was used to support these two unplanned contingencies. Second, the drawdown reduced squadron primary assigned aircraft (PAA) from 24 to 18 per squadron. In essence, the two major events of 1992—continued deployments in the Gulf and defense force structure reductions—acted independently to increase the operations tempo. General Fogleman best summarized the O&M budget controversy when he addressed troops in the Gulf:

> We are not funded for contingencies and crisis: It becomes critical . . . that Congress provide US supplemental dollars or a hollow force looms on the horizon.[69]

O&M funding was further degraded by DOD budget allocation decisions. From FY 1990 to FY 1995 DOD continually increased allocated O&M funding from conventional unit flying programs to nontraditional defense funding authorizations such as environmental cleanups, drug interdiction, peacekeeping, economic base conversions and noncombatant medical research.[70] The government spent $3.1 billion in FY 1990 on non-defense missions and $13.3 billion in FY 1995. This steady transfer of funds further strains an already limited O&M budget.

There are several key factors that are the primary forces generating declines in the readiness indicators. Most notably, across-the-board reductions in RSD buy funds, RSD repair funds, SSD funds, and O&M funds. Yes, aging aircraft is a significant factor, however, the primary factor is the RSD and SSD funding shortfalls and the subsequent shortage of depot level repairs.

Readiness Analysis Using Modeling Techniques

The second method of analysis applied multiple regression techniques on the four factors that were identified as possible influences on F-15C readiness. By inputting historical data into a multiple regression model, the study investigated the decline in FMC from 1990 to 1995.

Why a multiple regression analysis? In *Practical Business Statistics,* Paul Siegal identified three reasons justifying multiple regression analysis:[71]

1. Analyze a complex relationship consisting of many independent variables.
2. Forecast or predict future trends.
3. Process control by identifying internal and external trends.

This study analyzed the independent variables influencing the F-15C FMC rate and investigated the relationships between those variables. Also, the regression analysis provided a prediction equation that can assist the logistics managers with factors affecting future FMC rates. The analysis discovered several key relationships between internal and external relationships. The model analysis compliments many of the points developed in the previous section's analysis of maintenance statistics.

The Interactive Statistical Program (ISP) related the selected dependent variable (FMC) with six independent variables: TNMCM, TNMCS, breakrate, could-not-duplicate (CND), SSD shortfalls, and O&M funds. The data represented the period from 1990 to 1995 organized in a matrix of 23 statistical observations (See table B-3).

Three tests determined the statistical significance of the variables: the *f*-test for overall model significance; the *t*-test for individual model significance; and the *p*-test for individual variable significance.[72] All results fell within normally accepted statistical ranges. The ISP identified the regression model as *very highly significant*—the highest category which equates to a 99 percent confidence level (See appendix C-2).

Regression Analysis: FMC Variable Relationships

The model provided coefficients from the regression analysis which illustrate the interrelationships of the model coefficients and their respective variables (See appendix B). The range of coefficient was between +1 and -1. The stronger the relationship between variables, the closer to an absolute value of 1.[73] The closer values are to 0, the weaker the relationship between the two variables. Not surprisingly, very strong relationships exists between the TNMCM, breakrates, and FMC rates.

Likewise, moderately strong relationships exist between SSD, TNMCM and CND rates. Recall that SSD funding supports all consumable piece-parts. The more maintenance work, the higher the consumption of SSD funded bolts, washers, rings, etc. In fact, the SSD maintenance relationship would be higher than .470 if consumables were not purchased in high volume, resulting in a time-lag between usage and order.

The regression coefficient between O&M and TNMCM was + .405. Increased O&M funding means more repair dollars at the base level. However, the primary function of O&M dollars is to support the annual flying program.[74] Therefore, increased O&M funding increases the rate of flying which in turn increases the breakrates and TNMCM. This example points out the advantage of multiple regression because more than one variable is used in the analysis. Increased O&M funding improves the support process at the base level; but, it also increases operations tempo.

The regression coefficients analysis provided several results which initially appeared reversed. For example, the TNMCS and FMC had a +.196 relationship—low in magnitude, and wrong in direction. The increase of NMC supply time should decrease, not increase the FMC rate. The positive relationship can be explained by analyzing the strong negative relationship between TNMCS and TNMCM of -.626. Maintainers attempt to minimize TNMCM at all cost, including breaking another F-15C to get the part for a scheduled aircraft. Hence, the real world relationships between TNMCS and TNMCM explain the results of the regression between TNMCS and FMC. Because the FMC rate is more directly a result of maintenance, the relationship between supply and FMC is overshadowed and places the supply rates in direction of the FMC rate. Supporting this thesis is a -.375 inverse relationship between breakrate and supply. TNMCS affects FMC negatively, but the strong inverse relationship with the other maintenance metrics provides a statistically correct, but real-world anomaly between TNMCS and FMC.

Similarly, the coefficient table yielded a -.374 correlation between O&M and FMC. How could increases in O&M cause decreases in FMC rates? Obviously, the overall analysis must consider other variables. Increased flying hours drive up maintenance as O&M funding grows. These increases have strong adverse relationships with FMC which supersede the positive relationship between O&M spending and FMC rates. Bottom line: increased O&M dollars do buy more parts, but also buy more flying, which breaks more aircraft. The -.375 regression coefficient proves O&M has a stronger relationship with flying than with fixing.

The complex relationship between the many variables affecting FMC rate, and subsequent readiness, illustrates the difficulty for the maintenance planner. All these variables should be considered whether planning long-term preventative maintenance programs or deciding where to spend scarce dollars. The process is complex. Regression analysis is a valuable tool to assist in that decision-making process.

This section illustrated the advantages of regression analysis in decision-making. The limited scope of this study cannot provide the detailed regression analysis required for a complete analysis of the readiness controversy. However, this section revealed the benefits of regression analysis for the maintenance planner. For example, there were significant shortfalls from 1992 to 1994 in RSD actual and required funding that resulted in reduced FMC rates. Regression analysis could have identified the relationships between the different levels of shortfalls and the FMC rate. A thorough staff study, well versed in regression analysis tools, could provide an excellent view of the results of such drastic reductions.

Regression Analysis: Forecasting FMC

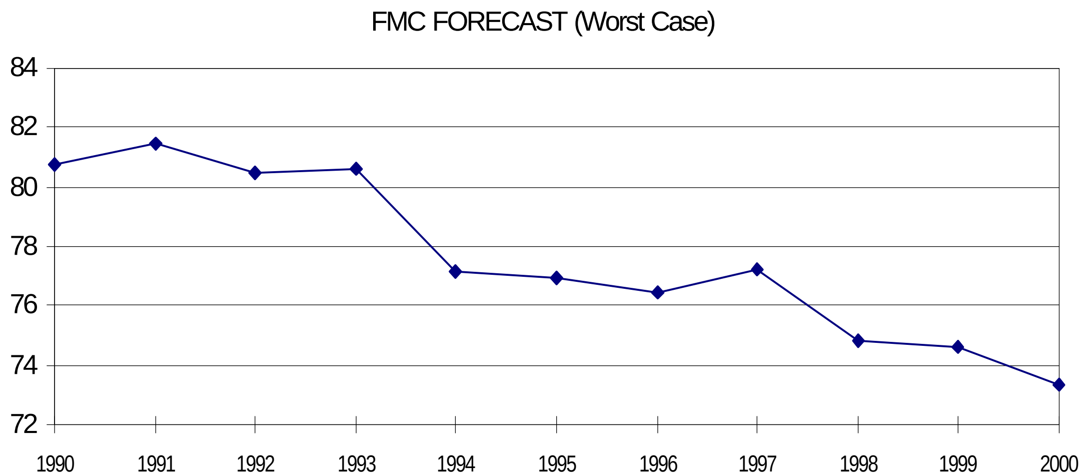
The regression analysis provided the coefficient constants to develop a prediction equation.[75] This equation started with the standard form:

$$Y=a+b_1x_1b_2x_2+...+b_px_p.$$

Using the coefficients provided from the regression analysis the following prediction equation was developed:[76] (See appendix C).

$$FMC=107.7-1.3(TNMCM)-.6(TNMCS)-.2(BRK)-.3(CND)-2.0(SSD)-.1(O\&M)$$

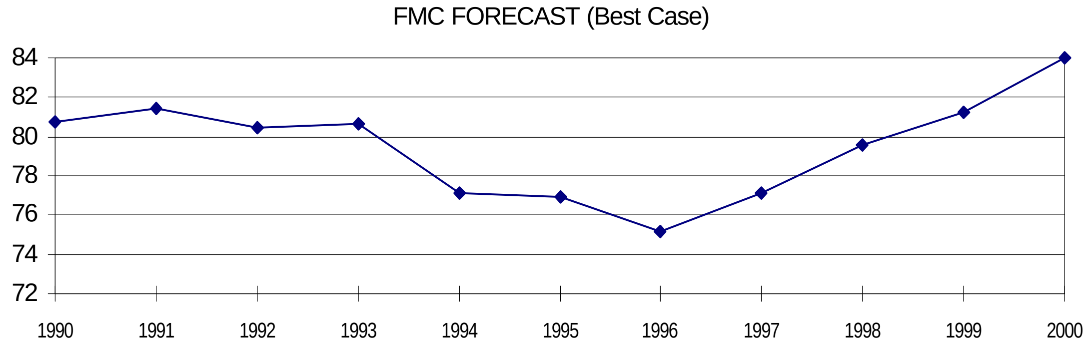
This prediction equation is a valuable tool to determine effects of changes in the independent variables. For example, future levels of funding can be inserted to predict the effects on FMC. Figures 2-15, 2-16, and 2-17 provide three FMC scenarios: best case, worst case, and most likely case. The results illustrate the benefits of a prediction equation. In addition to forecasting possible FMC curves, the prediction method also serves as an excellent vehicle to analyze the sensitivity of the FMC curve to corresponding changes from inserted variables (See appendix C).



Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

Figure 2-15. FMC Forecast (Worst Case)

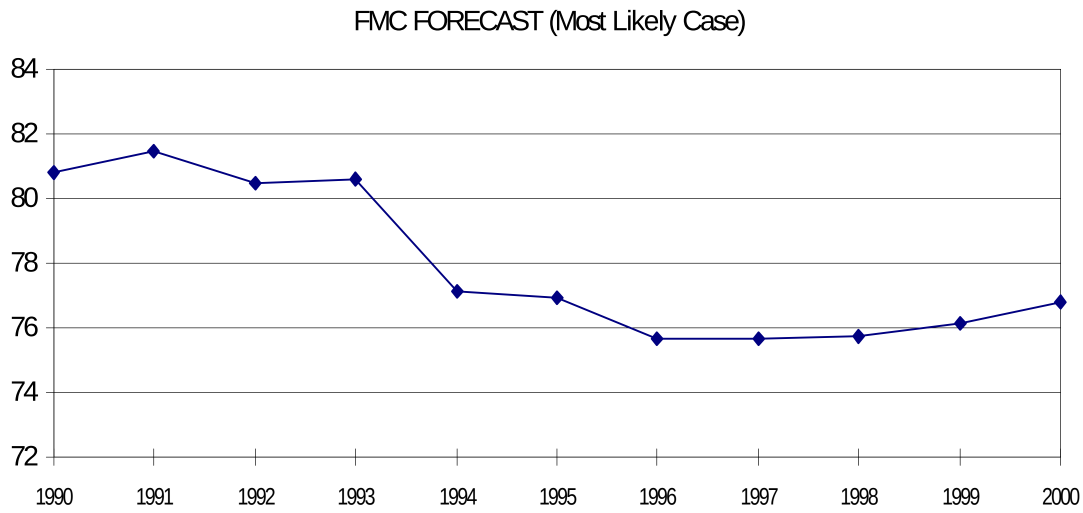
The worst case scenario led to increases in breakrates from 17 percent to 19 percent from 1996 to 2000; SSD funding reductions by 66 percent; increases in TNMCM from 13 to 15 percent; and TNMCS increases from 10 to 12 percent. All values were based within the range of previous parameters adding to the realism of the scenario. The slight FMC increase from 1996 to 1997 illustrates the importance of the breakrate input. The FMC rate did not decrease until the breakrate increased to 17 percent in 1998. The worst case scenario depicts breakrate as the most important factor to improve the FMC rate. Slight improvements in subsystem upgrades would achieve the two or three percentage points required to drive the FMC curve upward. (See appendix C).



Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

Figure 2-16. FMC Forecast (Best Case)

The best case scenario results from realistic increases in almost all values. The unrealistic portion of this scenario is not in the magnitude of the improvements, but in its breadth. It is highly unlikely the Air Force could fund programs to improve all areas. Key input values include a breakrate reduction from 17.9 percent to 9.0 percent and reduction of supply rates from 10.5 to 7.0 percent. These are realistic numbers based on past performance, but it is unlikely funds will be available to improve all of them. The best case inputs only increase the FMC rate to 84 percent, slightly above the standard MC value of 83 percent. This is profound because even the best case improves the FMC rate to just above standard values. (See appendix C).



Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

Figure 2-17. FMC Forecast (Most Likely Case)

The most likely case resulted from more conservative inputs in both magnitude and breadth. In the most likely case, breakrates were only decreased by 2.9 percent, supply rates by 1.5 percent, and total maintenance time by 1.4 percent. With no surprise, these small improvements only resulted in marginal effects on FMC. This reveals that unless the F-15C is upgraded in key subsystems such as radar, engines or secondary structures, low FMC rates will be the norm (See appendix C).

The three scenarios illustrate the sensitivity of the FMC curve to several key parameters, most notable breakrates. The analysis depicts the importance of regression modeling in long-term maintenance planning. In the modernization chapter, subsystem upgrades will be evaluated that can actually improve the breakrates to achieve the desired improvements in FMC projections.

Regression analysis provides a valuable tool to evaluate trends from past histories to predict future effects of various budget and force decisions. Specifically, the analysis provided an evaluation of the FMC rate, the most prominent readiness concern for the

F-15C. Analysis of the regression model yielded several important observations. The FMC rate is a function of many complex interrelationships. As expected, maintenance actions reflected in TNMCM and breakrates had a strong affect on the FMC process. However, the regression analysis provided insights into more complex, less noticeable maintenance factors. SSD, O&M and RSD were identified as key players in the process, both with FMC and with each other.

In addition, the regression analysis produced a prediction equation that forecasts FMC rates based upon variations in a set of measured variables. Although more detailed regression analysis is required for real-world decision-making, the prediction equation provides approximations that support the case for regression analysis as an additional tool in the maintenance planner toolbox.

Recommendations

Recommendation One

A model should be developed relating readiness to the three types of funding (RSD, SSD, and O&M). The regression analysis model developed in this section demonstrated the basic principles. The key to long-term planning is an accurate forecast of the relationship between RSD and SSD funding, O&M funding, and readiness.

Recommendation Two

Streamline the logistics system. The current system is efficient for large bulk shipments but inefficient in moving small quantities point-to-point. The improvements in transportation in the commercial industry must be explored for further transition to the Air

Force logistic system. Granted, the two-level engine concept appears unsuccessful; but, the avionics initiative appears to be working. Significant gains can be achieved.

Recommendation Three

Create an obsolescence review board to investigate the growing obsolescence problem. Obsolescence is currently at the embryonic stage and it must be closely observed. It could expand beyond manageable levels. Similar problems existed in the aircraft industry in the interwar years and the Morrow Board created government sponsored research programs to keep the aircraft industry viable.[77] A panel of national experts on logistics, acquisition and the industrial base should formulate a national long-range strategy with emphasis on the microelectronics industry.

Recommendation Four

Closely monitor the indicators related to the aging aircraft syndrome. Currently, the situation is manageable. However, if the F-15C is extended out to 2014, indicators must be observed for major increases in system failures. Closely associated with this concern is system upgrade programs that are discussed in chapter four on modernization. The breakrate is the best indicator to monitor the aging aircraft syndrome.

Conclusion

The ability to achieve air-to-air superiority early in a campaign is at the very heart of airpower doctrine. This chapter reviewed the first of three pillars of defense assessments—readiness. A thorough literature search was conducted, followed by two analysis methods that investigated the near-term readiness posture of the F-15C.

The analysis concentrated on three recurring factors identified in the literature search: aging aircraft, supply cycle and spare parts, and funding shortfalls. Analysis of logistical statistic histories from 1990 to 1995 determined the primary culprit of today's readiness. Near-term readiness problems for both the airframe and its engine were caused by dramatic reduction in four funding categories from FY 1992 to FY 1994. Most significant were the 60 percent reductions in RSD-buy funding in FY 1992 and FY 1993, 61.5 percent reductions in SSD funding in FY 1992 and a 25 percent reduction in O&M funding in FY 1993. Although budget officials have increased funding levels to 100 percent, the severe F-15C parts shortages created by the funding shortfalls will take several years to overcome.

In addition, other factors have influenced the readiness of the F-15C fleet. Increased operations tempo coupled with a decline in supporting O&M funding was a significant contribution. Likewise, obsolescence from an eroding industrial base has made certain microelectronics parts unsupportable.

Despite several negative indicators, the outlook for F-15C readiness is good. The budget has already been corrected to 100 percent authorization levels in all four categories. Also, the systemic factors which are not controllable, such as major structural problems, are not evident. However, there are hollow-force clouds on the horizon. Fortunately, senior leaders in the Air Force have made a strong commitment in funding to offset the approaching storm. The trick will be to balance the defense budgets with a long overdue modernization program that will ensure long-term readiness into the twenty-first century.

Notes

[1] William J. Perry, *Annual Report to the President and the Congress* (Washington: GPO: 1995), 37.

[2] Lynn Grile, Reliability Analyst, Dynamic Research Corporation, "1990-95 F-15C and F-16 maintenance statistics," 12 December 1995.

[3] Ibid.

[4] Briefing, Franklin C. Spinney, subject: Anatomy of Decline, 1994.

[5] House, *National Defense Authorization Act for Fiscal Year 1995: Hearings before the Subcommittee on Military Readiness of the Committee on National Security*, 103d Cong., 1st sess. (Washington, D.C.: GPO, 1994), 376.

[6] Ibid., 569.

[7] John Tirpak, "Hollow Pockets," *Air Force Magazine* 77, no. 12 (December 1994): 52.

[8] Ibid.

[9] Peter Grier, "Snapshots of a Force on the Move," *Air Force Magazine* 78, no. 6 (June 1995): 61.

[10] Perry, 641-42.

[11] Robert S. Dudney, "Aerospace World," *Air Force Magazine* 78, no. 1 (January 1995): 13.

[12] Ben Hollingsworth, Financial Manager, WR-ALC/LFCF, telephone interview with author.

[13] Ibid.

[14] Sheila E. Widnall, "Widnall Assesses the Force," *Air Force Magazine* 78, no. 4 (April 1995): 33.

[15] House, *Department of Defense Appropriations for 1995: Hearings before the Subcommittee on the Department of Defense of the Committee on Appropriations*, 103d Cong., 2d sess. (Washington, D.C.: GPO, 1994), 26.

[16] Ibid., 27.

[17] Hollingsworth, telephone interview.

[18] Maj K. Mills, ACC/LGF15, memorandum to Col Belisle, ACC/LGF, 22 August 1995.

[19] Briefing, WR-ALC/LFE, subject: Avionics Obsolete Parts, 4 December 1995.

[20] Ibid.

[21] Jerry Gibbs, Program Manager, Unohali Corp., telephone interview with author, 18 December 1995.

[22] Eric L. Gentsch and Donna J. S. Peterson, *A Method for Industrial Base Analysis: An Aerospace Case Study* (Bethesda, MD.: Logistics Management Institute, 1994), 8.

[23] Ibid., 3.

[24] Briefing, Avionics.

[25] Ibid.

Notes

[26] Maj K. Mills, ACC/LGF15, memorandum to Col Bjoring, ACC/LGF, 12 May 1995.

[27] Perry, 94.

[28] Lt Col Ted Bolds, "Maintaining the Defense Industrial Base" (Air War College Paper, 2 May 1994).

[29] Briefing, WR-ALC, subject: Obsolete Parts, Diminishing Manufacturing Sources, Vanishing Vendors, n.d.

[30] Jerry Vaughn, Avionics Manager, WR-ALC, telephone interview with author, 4 March 1996.

[31] Briefing, WR-ALC/LFE, subject: F-15 Display Subsystem Trade Study, 15 August 1995.

[32] Gibbs, telephone interview.

[33] Kenneth Girardini, et al., *Improving DOD Logistics*, RAND Report DB-148-CRMAF (Santa Monica, CA: RAND Corporation, 1995), vi.

[34] Rick Eden, et al., *Reinventing the DOD Logistics System to Support Military Operations in Post-Cold War* Era, RAND Report (Santa Monica, CA.: RAND Corporation, 1994), 700.

[35] John Tirpak, "Washington Watch: The Risk of a 'Hollow Future,'" *Air Force Magazine* 78, no. 5 (May 1995): 19.

[36] Eden, 98.

[37] I. K. Cohen, R. A. Pyles, and R. A. Eden, *Lean Logistics: A More Responsive, Robust, and Affordable System*, RAND Report DRR-630-AF (Santa Monica, CA: RAND Corporation, 1994), 99.

[38] Eden, 99.

[39] Chief Dyer, ACC/LGF15, telephone interview with author, 4 December 1995.

[40] Ibid.

[41] Eden, 703.

[42] Lt Col Andy Busch, DLA logistics officer, telephone interview with author, 11 Mar 1996.

[43] Cohen, 99.

[44] Eden, 102.

[45] Girardini, 26.

[46] John B. Abell and L. L Shulman, *Evaluations of Alternative Maintenance Structures*, RAND Report R-4205-AF (Santa Monica, CA: RAND Corporation, 1994), 43.

[47] Widnall, 33.

[48] Ibid.

[49] Debbie Delano, F100 Turbine Manager, SA-ALC/LP, telephone interview with author, 25 March 1996.

Notes

[50] Jeff Hill, TICARRS Database Manager, WR-ALC/LF, 1990-95 F-15C maintenance statistics, 6 December 1995.

[51] Grile.

[52] ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

[53] F. Stanley Nowlan and F. Howard Heap, *Reliability Centered Maintenance* (Los Altos, CA.: Dolby Access Press, 1978), 46-47.

[54] Mills, memorandum to Col Belisle.

[55] Ibid.

[56] Briefing, ACC/LGF15, subject: F-15 Modernization, 17 October 1994.

[57] "The US Air Force in Facts and Figures," *Air Force Magazine* 78, no. 5 (May 1995): 54.

[58] "The CBO's Air Force," *Air Force Magazine* 78, no. 3 (Mar 1995): 30.

[59] Peter Grier, "Snapshot of a Force on the Move," *Air Force Magazine* 78, no. 6 (June 1995): 61.

[60] Briefing, ASC/LP, subject: F100 Engine Status, 17 January 1995.

[61] Grile.

[62] Hollingsworth, telephone interview.

[63] Ben Hollingsworth, WR-ALC/LFCF, memorandum for record, subject: RSD/SSD Funding, 13 December 1995.

[64] Fred Mullis, Pratt & Whitney Customer Service Rep, P&W SA-ALC, USAFE F100 Overview: Mar 94-Mar 95 (DO42), 12 December 1995.

[65] Ibid.

[66] "US Air Force in Facts and Figures," 41.

[67] Betsy Mullis, Chief, Integrated Logistics Branch, WR-ALC, interview with author, 31 October 1995.

[68] Hollingsworth, memorandum for record.

[69] Suzann Chapman, "Aerospace World," *Air Force Magazine* 78, no. 3 (March 1995): 11.

[70] Pat Towell, "GOP Faces a Clash of Priorities with its Bid to Boost Readiness," *Defense & Foreign Policy*, 14 January 1995: 168.

[71] Andrew F. Siegel, *Practical Business Statistics* (Burr Ridge, IL.: Irwin, 1994), 163.

[72] Ibid., 475.

[73] Ibid., 501.

[74] Hollingsworth, telephone interview.

[75] Siegel, 478.

[76] Siegal, 480.

[77] I. B. Holley, *The United States Army in World War II*, Special Studies, *Buying Aircraft: Matériel Procurement for the Army Air Forces*, (Washington: Office of the Chief of Military History, 1964), 46-47, 89.

Chapter 3

Force Structure: The Bad

Even if the force were well funded, it would be inadequate to the task defined by the 1993 bottom-up-review of defense needs—the ability to win two nearly simultaneous regional wars.

—Floyd D. Spence (R-SC)

Introduction

Critical decisions. The preceding chapter analyzed the US short-term readiness posture. This chapter investigates the current F-15C structure and its ability to fight and win in two major regional conflicts (two-MRC). Are there enough F-15Cs to control the airspace? Is the two-MRC strategy outlined in the—bottom-up-review (BUR) still a viable strategy? John A. Tirpak, senior editor of *Air Force Magazine*, contends the two-MRC strategy is dead and US leaders have already decided to provide funds for only one-MRC.[1]

How much is enough? The decision is both critical and complex. The ramifications are enormous for the US and its role as a major power going into the next century. Too small of a force structure would be catastrophic. The Gulf War serves as a testimony to the United States's dependence on airpower. It is noteworthy that the last time the US lost a major land battle was also the last time it entered into a large land engagement without air superiority—1943 Kasserine Pass, Tunisia.[2]

The 1993 BUR developed the blueprint for the current force structure based on a two-MRC. The BUR based its findings on the assumption the US could become involved in two 1991 Gulf War size conflicts nearly simultaneously. Consequently, the BUR determined the Air Force should maintain a force of 20 tactical fighter wings.[3] In addition, the BUR recommended 20 percent of all tactical fighters be air superiority fighters.

The force structure debate rages around other controversial topics. The proliferation of advanced fighter technologies available on the open market is a critical force structure issue. Also, the USAF may be entering a revolution in military affairs (RMA) era. If so, can the ability to maintain air superiority be based on a 1970s stove-piped force structure model?

This is a difficult situation, but the decisions made are vital to US national security. As the US enters the twenty-first century, senior leaders will have to determine force structure issues that will shape the armed forces. This chapter investigates those issues and concludes with four recommendations.

Literature Search: Force Structure

How much is enough? Today's force structure consists of 20 tactical fighter wings of which only 13 are still active duty.[4] This compares to 38.5 fighter wings in 1985.[5] The air-to-air force consists of 4.1 wings (3.5 wings active duty). Supporting the air-to-air mission is the multiroled F-16 that shares both air-to-air and air-to-ground missions.[6] The actual F-15C force consists of 412 aircraft.

Five general force-structure topics were investigated during the literature search: the service life of the F-15C Eagle, the growing multirole gap in the tactical fighter force, both peer and emerging threats, fiscal constraints, and the effects of the RMA on force structure.

F-15C Service Life Limit

With an average usage of 270 aircraft flight hours per year, the F-15C fleet is approaching its service-design-life limit of 4,000 flight hours.[7] Following successful airframe structural testing, the F-15C will be extended to an 8,000-hour service life limit (See appendix D). Service-life limit is critical in the F-15 force structure equation. Therefore, an 8,000-hour service limit provides current levels of F-15Cs through 2010. Likewise, a 10,000-hour service limit would provide F-15Cs to 2020, while a 12,000-hour service life extends the F-15Cs to the year 2030.[8]

Losing the F-15Cs because of service-life limitations dramatically degrades the air-to-air mission despite the planned purchase of 442 F-22s. With the multirole F-16 approaching the service-life limits of its airframe around 2003, the extension of the F-15C service life becomes even more critical.

The Multirole-Gap in Tactical Fighters

The Air Force must meet the BUR requirements for multiroled fighters. As directed in the 1993 BUR, 40 percent of the fighter force must consist of multirole fighters.[9] But, the service-life limit of 200 F-16A/B models was reduced because of structural concerns in the F-16's airframe.[10] Forecasts indicated the first F-16s will reach their reduced service-life limits in the year 2003. In essence, even with the fully funded procurement of 442

F-22s, there will be a multirole-gap early in the twenty-first century unless additional F-16s are purchased.[11]

Maj Gen David J. McCloud, Headquarters USAF Director of Operations, explained the multirole shortfalls to the Senate Armed Services committee in May, 1995, when he stated:

> The Air Force will come up short about 1.5 to 1.6 wings of combat coded airplanes in the first decade of the twenty-first century unless there's a course change. We calculated a need for another twenty F-15Es and approximately 120 F-16s to avoid eating into the fighter force after 2000.[12]

ACC has seriously considered a new role for the F-15C as a multirole fighter to alleviate the F-16 shortfall. Changing the F-15C to a multirole fighter, responsible for both air-to-air and air-to-ground missions, is very controversial. Granted, re-tasking the F-15C to the multirole mission solves the shortfall, but not without consequence.

Retasking the F-15C as a multirole fighter creates several problems. Pilots would have to learn both air-to-air and air-to-ground missions. The training required to give the pilots minimal proficiency in the air-to-ground mission would detract from their existing air-to-air mission. From the pilot's perspective, the unique skills required in the air-to-air mission demand constant training.

The adverse effect of training and flying multirole missions is not limited to pilots. F-15C maintenance is already strained with 20 percent breakrates, aging aircraft subsystems, and an inadequate supply system. When air-to-air aircraft munition configurations are mixed with air-to-ground munition configurations, the additional man-hours required from crew chiefs, weapons-loading and specialist flights, create additional problems. The additional man-hours to reconfigure each aircraft would be significant, especially considering the existing workload already placed on aircraft maintenance personnel.

In addition, the effects of multiroling on the aircraft's airframe must be considered. When configuring the aircraft for air-to-ground missions, the gross takeoff-weight is significantly increased.[13] This would affect the mean-time-between-failure (MTBF) rates of the brakes, tires, and landing gears. Also, by flying an air-to-ground mission, the F-15C would fly with increased weights that may increase the structural wear on the airframe.

Air-to-ground missions force the flight envelope down to a low-altitude regime from the higher altitudes of the air-to-air mission. The airframe would encounter increased aerodynamic turbulence associated with low altitudes. Turbulence could increase the structural wear and tear on the flight control structures.[14] Many pilots feel similar low altitude turbulence caused the structural problems on the F-16A/Bs that resulted in a reduced service life.[15]

Air Force Manual 1-1 addresses the aircraft multirole tasking. *AFM 1-1* states, "The need to preserve the flexibility and versatility of aerospace forces does not mean all equipment must be designed to do *everything*" (Emphasis added). *AFM 1-1* identifies a *compromise-in-design* syndrome as a serious drawback to multiroling. It states that the aircraft's performance is reduced with each additional multirole design feature.[16] For example, the additional structural components required for the air-to-ground mission adds weight to the airframe which is a major design concern for the air-to-air aircraft designer.

The multirole gap in the US tactical fighter force is a problem that must be addressed. Based on the guidelines from the 1993 BUR, the multirole mission and the air-to-air mission are key ingredients in the two-MRC force structure. A review of the growing capabilities of potential adversaries reveals the two-MRC strategy based on 20 fighter wings cannot afford any gaps.

Potential Adversaries: Peer Competitors.

Force structures cannot be determined without a review of potential adversaries. This literature search was limited in scope due to security limitations. This section reviews two categories of adversaries: peer competitors and emerging regional threats. Russia and China are examples of potential peer adversaries while Iran, Iraq, and North Korea are examples of regional threats.

Recently, Russia has experienced dramatic economic and political changes. One author stated that the Russian Air Force is currently in a low state of readiness. During the recent Chechnya offensive, Russian pilots received fewer flying training hours and their maintenance support was poor. Spare aircraft parts availability was fifty percent below normal resulting in a very low mission-capable status.[17] Although there are serious problems within the Russian Air Force, they are still a potential threat.

The Russian air superiority mission is centered around the Su-27 aircraft. Although their army and navy curtailed most of their modernization programs, the Russian Air Force continues to receive advanced fighters.[18] Currently, two major modernization programs are underway: an Su-27 upgrade called the Su-35 and an F-22 type fighter called the MiG 1.42. The Su-27 is the counterpart to the F-15C and is Russia's front-line, all weather, air-superiority fighter. Since the Su-27 first flew in 1977, it has been upgraded seven times.[19] The current P series includes the Su-27 LL-PS with thrust vectoring nozzles on its engines. Although the F-15C and Su-27P series are similar in many categories, the upgraded Su-35 possesses significant advantages with its 14 air-to-air missiles and phased array radar (See table 3-1).

Table 3-1. Comparison of Air Superiority Fighters

TYPE	QUANTITY	FIRST FLIGHT	MISSILES STORES	THRUST TO WEIGHT	MAX SPEED	RADAR
F-15C	412	1972	8 AAM	1.64	MACH 2.2	APG-63 DOPPLER
SU-27	350	1977	10 AAM	1.60	MACH 2.35	PHASED ARRAY
SU-35	11	1985	14 AAM	1.65	MACH 2.35	PHASED ARRAY

Source: *Jane's All The World's Aircraft 1995-96*, ed. Paul Jackson, (Jane's Information Group, 1995).

The Su-35 phased array radar is superior to the APG-63 Doppler radar in both detection range and tracking capabilities. Additionally, the Su-35 propulsion system increases the aircraft's maneuverability with thrust vectoring nozzles.[20]

The Russians are designing a next-generation MiG-29 called the MiG-1.42. While still highly classified, it is expected to have twin tails and a blended body design similar to the F-22. It also has special surface materials and shading to enhance its stealth characteristics.[21] It is designed specifically to counter the F-22. This Russian multirole aircraft is not expected to enter service until after 2000. These fighters can be configured to carry the AA-11 Archer Infra-Red (IR)-guided missile; arguably the best missile in the world. It is also capable of carrying the AA-12 Adder active radar-guided missile; a missile equivalent to the US built AMRAAM.[22]

With Russia possessing state-of-the-art missiles and a first-rate fighter, the past policy of defeating the Russian quantitative advantage with F-15 qualitative advantage is no longer valid. The Su-35 series will be fielded before the end of the century. As stated earlier, the Su-35 is superior to the F-15C in several key areas and the Su-27 is qualitatively and quantitatively equal to the F-15C.[23]

The Chinese Air Force is modernizing their air-to-air capability with the Russian Su-27. China received 26 Su-27s in 1991 and 24 in 1995 under special license manufacturing agreements.[24] The Chinese plan to use the licensing agreements to modernize their forces and to develop an organic Su-27 production capability. Current intelligence estimates predict China will field its first organically produced Su-27 (Chinese F-10) by 2005.[25] As the Chinese industrial base expands, their ability to develop a self-sufficient modern fighter base will also grow.[26]

However, today the Chinese have several significant deficiencies in their air-to-air capability. Although they have a very large force structure consisting of 5,224 fighters, only 124 are considered advanced modern systems.[27] Due to a rudimentary logistics system, their fighter units only generate one training sortie every four or five days. This equates to 110 annual flying hours per pilot compared to 250 to 300 annual hours for USAF pilots.[28] The Chinese Air Force is mainly composed of obsolete aircraft maintained with a decaying logistics system.

Nonetheless, China is a rapidly growing economic power that desires to have superpower status and could evolve into a formidable military power.[29] James Lilley, former ambassador to Beijing, believes China aims to modernize its forces and begin expanding its influence into the South China Sea in what some refer to as *creeping regionalism*.[30] If not in this century, then certainly early in the next century, the US will need the wherewithal to defeat a modernized Chinese Air Force.

Potential Adversaries: Niche States

In addition to peer competition, other developing nations may prove to be adversaries of the US. In his book *Future Wars*, Colonel Jeffrey Barnett terms these developing nations as *niche states*.[31] Similarly, as developing nations expand, many will enter what Dr. Magyar identifies as *nationally expansive stages*.[32] The explosion of emerging states with expanding gross domestic products will complicate an already complex global military strategy.

As these niche states grow economically, their ability to buy aircraft from more developed states may result in a capability to influence neighboring nations. These niche states could purchase gray-threats—aircraft built by friendly countries and exported to the niche states. The gray-threats offer a definite challenge to the F-15C.[33]

For example, the newest French fighter to enter the export market is the Dassault Aviation Rafale scheduled for production in 2001. Designed as a multirole fighter, it has a stealthy design and a radar cross-section at least 10 times smaller than current French fighters. It has advanced flight controls and a state of the art radar system that makes it a formidable threat to the F-15C. France is marketing this fighter throughout the Persian Gulf and Southeast Asia regions.[34] Undoubtedly, this will be a weapon-of-choice for many developing niche states desiring to dramatically improve their air superiority capabilities.

As the US plans for its force structure into the twenty-first century, it must consider both niche states and peer competitors. The days of developing force structures based on a single, well-defined peer competitor disappeared with the fall of the Berlin Wall. The proliferation of high technology to niche states makes long-term force structure planning very difficult. Unfortunately, US force structure planning and budgeting must account for the complete range of adversaries—regardless of cost.

Tough Choices: All a Matter of Money

There are two reasons why planning is difficult. First, the difficulty in forecasting US force structure stems from the lack of a clearly defined threat. The current military situation has been extremely dynamic since the end of the Cold War. General Shalikashvili recently wrote, "The combination of slower modernization rates and a rapidly changing threat environment makes long-range planning more difficult and more important."[35]

Second, the US Congress is reviewing the federal budget in search of potential savings. A bill was recently introduced into legislation that would require the budget to be balanced within seven years. American opinion polls indicate taxpayers will not support major increases in defense spending. A recent CNN poll showed the American public is opposed to increased defense spending as part of the Republican Party's 10 point "Contract With America". The largest negative rating among the 10 points in the contract was the defense spending increase proposed by the Republican Congress.[36]

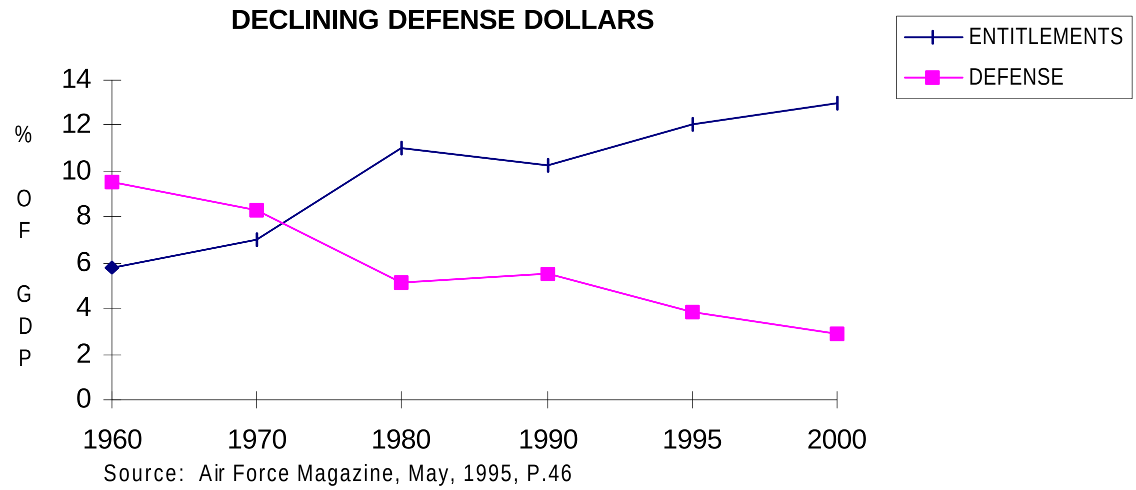


Figure 3-1. Declining Defense Dollars

Entitlement spending has increased at the expense of defense spending (See fig. 3-1). Granted, the force structure has been reduced, but maintaining a ready and modernized force on 2.9 percent of Gross Domestic Product (GDP) is difficult. The current 3.8 percent GDP represents a 60 percent decrease since 1960.

The 1997 budget allocates $38.9 billion for weapons procurement. This is the lowest amount since WWII. In the past, the principle opponent of defense hawks was domestic doves. Today, deficit hawks are looking for ways to cut military spending.[37] Simply stated, US military force structure will not get additional funding.

Force planning is complicated by a readiness-versus-modernization competition. In recent years, readiness increased at the expense of force structure and modernization. Although the defense budget has declined by 34 percent in the last 10 years, the short-term readiness has increased in the O&M budget since 1994. In 1996, 37.4 percent of the defense budget is allocated to O&M for short-term readiness, 27.9 percent for military personnel, and only 18 percent for system procurement. Emphasis needs to shift from near-term readiness to long-term readiness. This is reflected in a recent article in the *National Review*:

> While many defense experts argue that the administration [Clinton] has maintained the near-term readiness of US forces, they are concerned that this is being accomplished at the expense of long-term readiness, by dipping into funds earmarked for modernization and re-capitalization.[38]

There does appear to be a gradual shift towards modernization. This is reflected in the 1997 budget. Procurement will increase from 18 percent in 1996 to 31 percent in 1997. O&M readiness funding will decrease from 37 percent in 1996 to 23 percent in 1997.[39] However, this shift will be at the expense of force structure. Lt Gen George Muellner, a senior Air Force acquisition officer, recently stated, "I think most of the indications are right now that you are probably going to see some decline in force structure because of the need to re-capitalize and reinvest in other areas."[40] The current trend of reducing force structure to fund modernization could also be a result of a technology explosion in what may be termed a revolution in military affairs (RMA).

RMA and Force Structure

Technology has dramatically impacted today's force structure planning. There was a dramatic reduction in force structures with the advent of the precision guided munitions (PGM). For example, in WWII 108 B-17s dropped 648,100 bombs on one power-generation station with a 96 percent probability of striking the plant. Today, the same probabilities can be achieved with a single aircraft and two PGMs.[41] Col John Warden, an air campaign planner, stated, "The combination of stealth and PGMs on the same platform has greatly reduced force packages resulting in our ability to make up large deficiencies in numbers."[42] In addition, the stealth-PGM combination has enabled air planners to move from serial attack to parallel attack. Serial attack was used during WWII. This means bombing the same target until it is destroyed and then moving to the next target. Parallel attack is a tactic where bombers attack multiple targets simultaneously. By attacking in parallel, the rate-of-effect is greatly accelerated. This new tactic greatly reduces the force structure required to accomplish air campaign objectives.[43] The best example of force structure reduction was cited by Col Deptula in his recent article "Firing for Effect: Change in the Nature of Warfare." In a Libyan-type raid, he contended 36 airman flying six B-2s and six support aircraft could accomplish the same mission that previously required two carrier battle groups, 12,000 people, 20 ships and 132 aircraft.[44]

Air-to-air warfare has not undergone an RMA similar to air-to-ground warfare with the stealth-PGM combination. The F-22 will be stealthy, but will only employ the mid-range AIM-120 air-to-air missile. A new technology level will be achieved when the stealth F-22 fighter is integrated with a long-range air-to-air missile (greater than 150 mile range) with possible tracking inputs from other sources. The effect would be dramatic. A handful of stealth fighters could gain complete air superiority almost instantaneously. The result would be a modern day Battle of Crece. Here, 10,000 French soldiers were killed with negligible losses to the English using new longbows that extended their arrow's reach beyond the reach of the French crossbows.[45]

Interestingly, the Russians are working diligently in this area. Since 1985 they have fielded three long-range air-to-air missiles.[46] The AA-9 Amos was fielded in 1985 and has a range of about 100 kilometers (km). The AA-10 Alamo fielded in 1990 has a range of 40 to 110 km. Additionally, the Russians have just tested the R-33 that has a 150-km range and possibly a 400-km range when a booster rocket is attached.[47] Conversely, the longest range US missile is the Phoenix (built in 1974) with a maximum range of 60 to 70 miles.[48]

The challenge will be to integrate the developing microcircuitry in today's missiles with alternate off-aircraft acquisition platforms such as E-3s, satellites or Unmanned Aerial Vehicles. A datalink system could downlink the Global Positioning Satellite coordinates to a 150 to 200 km missile that will be launched from a standoff aircraft. Once the missile is in close proximity to the target, it could transfer to a more conventional tracking mode; truly, a twenty-first century long-bow reincarnation. Forty percent of all US air kills in the Gulf War were beyond visual range. This is an indication the US is approaching the next level of air warfare.[49] The stealth fighter, integrated with a long-range air-to-air missile, will drastically reduce future force structures. A handful of *stealth-long-bows* could wreak havoc on enemy forces.

But, is the force structure really set? Can the US really begin to modernize its air-to-air aircraft? Some contend the two-MRC strategy cannot be met with the current 20 fighter-wing force. The answer to these questions is not in the available literature and the controversy is being decided as this paper is being written.

Force Structure Methodology

Does the US have enough F-15Cs in its force structure to meet the two-MRC strategy? This paper will analyze a hypothetical two-MRC scenario with North Korea and Iran. The study was restricted to an air-to-air war exclusive of land and sea engagements.

Data Collection Methods

The data was collected from three primary sources. The maintenance and logistics data was collected from Keaney's *Gulf War Air Power Survey*, Vol. 3, *Logistics and Support*. The sortie production and operational data was collected from *Gulf War Air Power Survey*, Vol. 5, *A Statistical Compendium and Chronology*. *Jane's All the World Aircraft* provided the force structure data for the North Korean and Iranian Air Forces. Although the sources provided a wealth of generic information, data conditioning was required. For example, overall mission capable rates and sortie production rates were available in Volume 3, but not represented by air war phases (See appendix E).

Analysis Procedures

The analysis was based on a two-MRC model developed from actual data collected from the 1991 Persian Gulf War. Sortie production, maintenance statistics, and force structures were used as a baseline for the two-MRC scenario. Using the Gulf War data as a guideline, sortie and maintenance plans were developed within the confines of current operational and logistical parameters. This ensured realistic sorties and models were used.

Assumptions

The two-MRC analysis was based on the following assumptions:

1. Most importantly, both conflicts are fought against regional emerging states. Major powers such as China or Russia were not involved militarily.
2. All calculations and analysis are based on near-term force structures. Force structures were obtained from current available literature. Break-through technologies or planned modernization programs are not included.
3. Weapons of mass destruction are not used.
4. Coalition support in both theaters is equal to the level the Royal Saudi Air Force (RSAF) provided in the 1991 Gulf War; roughly 34 percent of Defensive Counter-Air (DCA) and Combat Air Patrol (CAP) missions. In the Iranian MRC, RSAF

will provide similar F-15C support. In the Korean MRC, the Republic of Korea (ROK) will provide equivalent support with 96 F-4s.

5. All analysis was based strictly on air-to-air missions. Ground attacks, airlift, sealift, and basing issues were not considered in the analysis.
6. All maintenance statistics used are attainable. Selected numbers were based on current maintenance standards. In the Gulf War all maintenance statistics were met or exceeded.

These assumptions, coupled with extensive reference to the Gulf War data base, ensured the analysis was based on realistic inputs. Consequently, a detailed analysis of current F-15C force structure in a two-MRC is now possible.

Force Structure Analysis

This force structure analysis evaluated the US military's ability to fight a two-MRC: one of today's most important strategic issues. Due to economic pressures, planners must cut force structure without affecting readiness. Today, with technology greatly accelerating the tempo and effects of modern air combat, the US cannot afford errors in defense sizing. Without air superiority, the modern airpower doctrine is in doubt. General Fogleman is concerned the American public has lost sight of the importance of air superiority. He recently stated:

> The nation as a whole has lost sight of how valuable air superiority is. For some reason, there are large numbers of people who think air superiority is a God-given right of Americans. [That's] absolutely not true.[50]

Historically, Americans have enjoyed the benefits of total air superiority. This feeling was magnified in the 1991 Gulf War when the US gained air superiority on the first night of the war. However, the lessons from Desert Storm must be reviewed with caution. The Desert Storm air campaign is only relevant in an MRC against regional powers.

Historical Baseline: Gulf War Air Superiority Mission

Can 300 F-15Cs achieve air-to-air superiority on two fronts in North Korea and Iran *nearly* simultaneously? Number of sorties, ratio of DCA to CAP missions, coalition sortie productions, and other data from the Gulf War will serve as a starting point for analyzing the two-MRC scenario.

When Iraqi forces crossed the border into Kuwait in August of 1990, the Iraqi Air Force consisted of 831 combatant fixed wing aircraft of which 350 were air-to-air fighters. For point defense, the Iraqis used MiG-25 air interceptors, older but highly maneuverable MiG-21s, multirole MiG-23s, modern MiG-29s, and French Mirage F-1s.[51] Their extensive air defense system, consisting of anti-aircraft guns and missiles, was seven times denser than that presented over Hanoi in the Vietnam War. Although a formidable regional airpower, they certainly were not a match for the USAF.[52]

The coalition forces led by the USAF formulated an awesome force. It consisted of 96 USAF F-15Cs; 110 F-14s; and 69 RSAF F-15Cs.[53] The USAF F-15Cs flew 4097 DCA missions and 461 CAP missions; this was sixty-six percent of the total air defense mission. The RSAF also contributed greatly with 2088 total F-15C sorties.[54]

The results were impressive. Air superiority was achieved on 17 January, the first night of the war. General Schwarzkopf declared total air supremacy on 27 January, 10 days after the air war started.[55] Coalition forces destroyed 33 fixed wing aircraft including two MiG-25s and five MiG-29s.[56] As a tribute to technology advances, over 40 percent of all kills were from beyond visual range.

However, the decisive victory by USAF and RSAF F-15Cs must be viewed critically. Very few of the Iraqi aircraft flew during the war. On the first three days of the war, the

Iraqis only flew 221 air defense sorties even though their country was under massive attack. Fourteen of the 33 kills occurred in the first three days.[57] In essence, the Iraqi Air Force realized it was suicidal to defend their skies against coalition air forces. This was a preplanned strategy by Saddam Hussein. In a speech prior to the air war, he told the Iraq National Assembly, “We will not use our Air Force, we will keep it. Two years hence our air force will still be in a position to pound Bani-Sadr and his collaborators.”[58]

There are two lessons-learned that can be transported to the two-MRC analysis. First, extensive air defenses do not curtail high altitude air defense missions. None of the USAF F-15Cs were lost to ground defense, and none of the 27 US aircraft lost were flying air defense missions.[59] Second, trends can be developed from the sortie production analysis of the Gulf War.[60]

1. USAF F-15Cs flew 4558 missions for a 50 sortie per aircraft average.
2. Almost 90 percent of the air-to-air missions were DCA.
3. An average of 138 sorties were flown during the first three days of the war. The USAF averaged 98 sorties per day after air supremacy was declared.
4. During the ground war, albeit only four days in duration, the F-15Cs flew 126 sorties per day.
5. The average FMC rate during the air war was substantially higher than the prewar FMC rate of 80.7 percent. Calculating data obtained from the Gulf War Air Power Survey yields an FMC rate of 93.6 percent from 17 January to 28 February.61

Each conflict is unique. However, it’s not unrealistic to compare selective data from the Gulf War to a two-MRC analysis between North Korea and Iran. Similar patterns can serve as a foundation for analysis. Would MRCs conducted nearly simultaneously against two regional powers such as North Korea and Iran achieve air supremacy within 10 days? In a word—yes. The operation and maintenance data from the Gulf War will be used as guidelines to prove this hypothesis.

A North Korea-Iran War: A Two-MRC Force Structure Analysis

Although many factors contribute to a MRC, only air-to-air factors were considered. Key issues such as land forces, naval forces and airlift support were ignored. However, the analysis of an Iranian-North Korean MRC was an excellent method to evaluate the current Air Force structures from strictly an air superiority perspective.

Iran is initiating a major modernization program; however, a small defense budget limits their near-term force structure.[62] Their 115 primary air-defense fighters consist of MiG-21s, MiG-31s, and F-14s. In addition, 58 multirole MiG-29s are used in the air-defense role. Due to limited flying hours, the Iranian pilots are not as well trained as their Iraqi counter-parts. Also, a severe parts shortage exists due to Western embargoes, which affects their training sorties. Consequently, the Iranians are in the transition from their western aircraft to Russian and Chinese models (See table 3-2).

Table 3-2. Iranian Air Order of Battle

AIRCRAFT	QTY	IN-SERVICE	MFTR	MISSION
1. F-7 (MiG-21)	70	65	China	Air Defense
2. Mirage F-1	24	12	France	Multirole
3. F-4 D/E	50	40	US	Multirole
4. F-14A	20	15	US	Air Defense
5. MiG-29	58	18 (Ordered)	Russia	Multirole
6. F-5	75	60	US	Multirole
7. Shenyang F-6	40	20	China	Multirole
8. MiG-31	25	25 (Ordered)	Russia	Air Defense
TOTAL	**362**	**230**		

Source: *Jane's Sentinel: The Gulf States 1994*, (Alexandria, VA. Jane's Information Group, 1994), 10-11.

With Chinese assistance in 1994, Iran integrated a command and control (C^2) surface-to-air missile system that greatly improved their air defense system. But, Iranian air defenses fall well short of what Iraq possessed in January of 1991.[63]

Assuming the RSAF provides a force comparable to its Gulf War effort, the US will achieve air supremacy within 10 days.[64] Attrition losses are estimated to be near zero. In fact, the 96 F-15Cs used in the Gulf War could be reduced in number if more F-15Cs are needed in the Korean theater. In essence, a similar force of 69 RSAF and 96 US F-15Cs would be sufficient to achieve air supremacy against a weak Iranian Air Force.

On the other hand, gaining air superiority and supremacy on the Korean peninsula is more difficult. Although the North Korean Air Force (NKAF) has problems similar to Iran, they do have a better fighting spirit. The North Korean air order of battle consists of an obsolete air force based on Russian designs of the 1950s and 1960s (See table 3-3).

Table 3-3. North Korean Air Order of Battle

AIRCRAFT	QUANTITY	MANUFACTURER	MISSION
MiG-29	14	Russia	Multirole
MiG -23	46	Russia	Multirole
MiG -21	120	Russia	Air Defense
J-5 (MiG -17)	80	China	Air Defense
J-6 (MiG -19)	60	China	Air Defense
J-7 (MiG -21)	40	China	Multirole
J-5 (MiG -17)	160	China	Attack
J-6 (MiG -19)	120	China	Attack
TOTAL	**640**	**3 Russian/5 Chinese**	**3 Air Defense**

Source: Asia-Pacific Defense Reporter: 1995 Annual Report, (Peter Isaacson Publishing, 1995), 128.

Although larger than the Iranian Air Force, the NKAF is smaller than the 1991 Iraqi Air Force. In addition, the number of modern aircraft is lower than both the Iranian and Iraqi Air Force. With a declining GDP, a modernization of the NKAF is remote. On the surface, it appears air superiority should be gained the same as it was in the 1991 Gulf War: almost immediate air superiority and 10 days for air supremacy.

Three factors would greatly increase the North Korean resistance compared to Iran or Iraq. First, it is generally perceived that the Korean pilots provide a much greater fighting spirit. Based on their performance in the Korean War (1950-1953) and their aggressiveness in the subsequent Cold War years, few pilots will eject at the first signs of radar lock-on as did the Iraqi pilots in the Gulf War. In a *US News & World Report* article entitled, "The Most Dangerous Place to Be," Joseph Galloway writes that pilots will fly their 160 J-5s and 1200 J-6s configured in attack modes on suicidal offensive-counter-air (OCA) missions against US and ROK airfields in the early hours of the war.[65] Disregarding all other factors, the fighting spirit of the North Korean pilots, however poorly trained, will account for some F-15C attrition.

Second, although the Koreans cannot offer a formidable air-to-air defense, they would employ an asymmetrical strategy against coalition Air Forces. Their 100,000 elite special operations forces (SOF) units would disrupt operations at all major allied airfields.[66] Highly trained and fanatical in devotion, thousands of SOF in wood-framed AN-2 Colts will fly southward deep behind allied lines. They will disrupt US and ROK Air Forces while still on the ground; most likely in conjunction with the suicidal J-5 and J-6 airfield attacks.

Finally, Korea would use their advanced Scud-B/C intratheater missiles. Although Iraq had little success in the Gulf War, the North Koreans Scud-B/C missiles have better range and excellent accuracy.[67] Recent Pentagon reports indicate only 50 percent of the Scud attacks could actually be defended against.[68] Several strikes at either Osan Air Base (AB) or Kunsan AB would have devastating effects. Lamberth, a noted defense technology expert, stated recently, "A single 500 pound bomb delivered through the roof of an F-15, F-16, or F-18 avionics intermediate shop could very well put the entire wing out of the war."[69]

Assuming allied forces can offset the expected attacks on the airfields, are there enough F-15C aircraft available after allocating 100 F-15Cs to the Iranian MRC? Recall that the operational F-15C force structure is approximately 300 aircraft assigned to operational units. Assuming 100 are allocated to the Gulf, and 100 are kept in attrition reserve, only 100 F-15Cs remain for Korea.

As in the Gulf War, the coalition would makeup the shortfall. In the Gulf War the RSAF provided 34 percent of the air-defense sorties.[70] Although the ROK Air Force maintains 48 F-16s and 96 F-4s, only the F-4s are assigned strictly the air-to-air mission. Therefore, the 96 ROK F-4s would contribute the same effort as did the RSAF in the Gulf War.

Other aircraft are available if needed. The multiroled F-16s could support the air-to-air mission, but most likely all available F-16s will support the air-to-ground mission against North Korean armor and mechanized infantry divisions. Finally, older USAF reserve F-15 A/B models could support part of the air-to-air role, if required.

Assuming coalition support in both theaters, the force structure is sufficient to provide 100 F-15Cs to an Iranian MRC and 100 F-15Cs to a Korean MRC while maintaining 100 aircraft attrition force. In conjunction with the 96 ROK F-4s, a sortie production equal to the 1991 Gulf War of 6,646 F-15C (combined USAF and RSAF) sorties could be flown.

Table 3-4. USAF Sortie Production Calculations

	Attrition to Enemy	US F-15C Sorties	Sorties per Day	US F-15C Assigned	US F-15C Sortie per Assigned	US F-15C Sortie per Aircraft	MC Rate	Abort Rate
Gulf War	0	4558 (42 Days)	108.5	96	1.13	1.19	93.6 (FMC)	3
2 MRC (Korea)*	36 (3%/day)	3600 (30 Days)	120.0	100	1.20	1.58	80.0 (MC)	5
2 MRC (Iran)*	0	3600 (30 Days)	120.0	100	1.20	1.58	80.0 (MC)	5

Source: Eliot Cohen, et al. eds., Gulf War Airpower Survey, vol. 5, A Statistical Compendium and Chronology, (Washington: GPO, 1993), 276-277.
***Note:** Calculated using Gulf War data as baseline. See appendix E.

In two theaters, 100 US F-15Cs will fly up to 3600 DCA sorties in a 30 day war (See table 3-4). From both a threat perspective and a logistics perspective the forces are available to meet a two-MRC war on the level of the 1991 Gulf War.

Coalition forces play a major role in the two-MRC force structure. Without the ROK and RSAF involvement, the existing USAF could not produce the sorties required in two separate theaters. The coalition forces provide an additional 30 percent in each theater—69 RSAF F-15Cs in the Gulf and 96 ROK F-4Cs in Korea for 1440 sorties in each theater. Note that a three-percent attrition loss was calculated in the Korean theater, whereas no attrition losses were calculated in the Iranian theater. Additionally, all lost aircraft were assumed replaced with the attrition reserve aircraft. Based on a three-percent attrition rate in the first 10 days of war at 120 sorties per day, 36 aircraft would be lost to enemy air operations. As in the Gulf War, with high altitude CAP and DCA missions, it is assumed there will be no losses to ground threats.

Logistically, the analysis assumed a conservative 80 percent MC rate in theaters. This compared to an actual 93.6 percent FMC rate during the Gulf War.[71] Although the 1990 FMC rates were lower, wartime conditions often change both reporting procedures and maintenance intensity levels. An 80 percent MC rate is very close to the real-world 1995 MC rate of 80.4.[72] A standard five percent abort rate for daily operations is assumed without spare aircraft available. Again, it is unlikely no spare aircraft would be available, but a worst-case scenario is being used.

Analysis of two-MRC scenario supports the 1993 BUR force structure based on conflicts in two geographically separated theaters with North Korea and Iran. Using 1991 Gulf War as a baseline, 300 F-15C aircraft can achieve air superiority and air supremacy in a theoretical two-MRC scenario. Although achieving air-to-air superiority with North Korea would be more challenging than the Gulf War, it still could be achieved in 10 days or less. This is assuming their anticipated attacks on allied airfields do not affect the sortie production.

Is this a comprehensive endorsement for the two-MRC strategy as outlined in the BUR? Absolutely not. In fact, even with the obsolete air forces of Iran and North Korea, a two-theater campaign required a 34 percent coalition involvement. Without coalition support the two-MRC strategy is not supportable.

Major powers were not factored into the model. However, they can have a significant impact. For example, if China were to enter the Korean War, they would immediately add 5,224 out-dated aircraft to the theater and 124 front-line fighters.[73] The 100 F-15Cs in theater would not be enough to cover the increased enemy strength. With 100 other F-15Cs allocated to the Iranian Theater and 100 required for attrition reserve, F-15As or F-16s are needed. But, the analysis was centered on using only F-15Cs as the primary air superiority fighter. Hence, the current F-15C fleet is adequate for only two-MRCs comprised of regional states. The introduction of a single near-peer competitor, like China, overextends the 300 F-15Cs. Bottomline: capabilities of the MRC players are the determining factor in the scenario, not the number of MRCs.

Recommendations

This chapter conducted a force structure analysis of a theoretical two-MRC war. From the literature search and subsequent analysis, four key proposals are presented.

Recommendation One

Purchase all 442 F-22s on schedule. The available F-15C fleet of 300 operational aircraft is adequate for a two-MRC only when the participants are niche states like North Korea or Iran. As these states develop, many will purchase advance fighters, such as Russian MiG-29s and the French Rafale 2000s. This will affect the ability of 300 F-15Cs to achieve quick and decisive air superiority.

Recommendation Two

Sell F-15Cs to the Republic of Korea. Provide technical and possible financial assistance through foreign military sales (FMS) to upgrade the 96 ROK F-4Cs to at least two squadrons of F-15Cs. In addition, FMS orders would assist the industrial base problem outlined in Chapter Two.

The outstanding contributions of the RSAF and their 69 F-15Cs in Desert Storm illustrate the enormous benefits from well-trained and well-equipped allies. Analysis indicates similar efforts would be provided in the theoretical two-MRC scenario. USAF force structure of 300 operational F-15Cs is not sufficient unless the ROK and RSAF contribute approximately 30 percent to the air superiority mission.

Recommendation Three

Create a single point-of-contact consisting of technical, doctrine and organizational experts to exploit the emerging revolution in standoff air-to-air warfare. Modern air forces are entering a revolutionary period. Air Force technologies and doctrines should explore the combination of the F-22 stealthiness with revolutions in long range air-to-air missiles. To apply the standoff technology, the doctrine must integrate alternate target acquisition platforms, high-speed data links, and long range missile designs.

Recommendation Four

Invest in a theater missile defense system that can counter the growing theater missile threat. Recent Pentagon reports of a projected 50 percent success rate with the current Patriot system is unacceptable in a Korean campaign—base operation on the peninsula would cease, thus reducing the existing force structure effectiveness. [74]

Base defense will define the future air campaign. The US and its coalition partners rule the skies in both man and machine, but future enemies will attack the USAF bases as key centers of gravity. Unable to confront the allies directly in air-to-air engagements, they will attempt to neutralize allied airpower through asymmetrical attacks with advanced missiles and elite SOF. US force structure is sufficient only if it is able to operate unmolested from bases on the peninsula.

Conclusion

The US military is indeed at a critical junction. Both the literature search and the analysis revealed critical issues to be addressed if the USAF is to maintain air superiority. However, the proper quantity and type of force structure are limited by economic, technical and political constraints.

The literature search confirmed four areas affecting force structure. First, the US needs to extend the F-15C service life to 8000 flight hours. Second, there are increasing threats by both peer competitors developing advanced aircraft systems and niche and emerging states purchasing advanced fighters from the gray-threat market. Although the current F-15C fleet is adequate for the near-term, there is a growing vulnerability as advanced technologies are transferred to the niche and emerging states. Third, a shortage of F-16 aircraft in the multirole mission early in the next century will directly affect the F-15C force structure. Reroling the F-15C to an F-16 multirole mission will not be without degradation to the F-15C's primary mission—air-to-air superiority. Finally, the opportunity exists to exploit technology, doctrine, and organization for an RMA integrating stealth and standoff missiles in the air superiority mission.

The analysis of existing force structure in a two-MRC determined the existing fleet of F-15Cs can perform the mission. But, the analysis of a theoretical two-MRC with nearly simultaneous conflicts in Iran and North Korea was based on several important assumptions. These assumptions are critical in both theory and reality. Most importantly, the ability of the existing force structure to be successful depends on coalition support, similar to that received from the RSAF in the Gulf War. Also, the analysis indicates a successful two-MRC should be limited to emerging or niche states. Either Chinese or

Russian involvement exceeds the current F-15C force structure. For this reason, the F-22 is critical for complete air superiority against all threats.

In closing, based on the most likely scenario of a two-MRC with regional powers, the US could clearly obtain air superiority in the near-term. However, this analysis verified there are valid concerns for the US air-to-air force structure. For long-term dominance of the air superiority mission the F-22 is a requirement. The F-15C will play an important supporting role, not a primary one.

Notes

[1] John A. Tirpak, "Washington Watch: The Risk of 'Hollow Future,'" *Air Force Magazine* 78, no. 5 (May 1995): 15.

[2] David Syrett, "Northwest Africa 1942-1943," in Benjamin Franklin Cooling, ed., *Case Studies in the Achievement of Air Superiority*, (Washington, D.C.: Center for Air Force History, 1994), 239.

[3] William J. Perry, *Annual Report to the President and the Congress*, (Washington, D.C.: GPO, 1995), 28.

[4] Ibid., 199.

[5] Gary C. McMahon, "Air Force Logistics Doctrine: Where is it?" Air War College Thesis, Maxwell AFB, AL, 1985), 23.

[6] Perry, 199.

[7] Briefing, McDonnell Douglas Aircraft Co., subject: F-15 Secondary Power System, 21 July 1995, 3.

[8] Ibid., 11.

[9] "The CBO's Air Force," *Air Force Magazine* 78, no. 3 (March 1995): 31.

[10] Ibid., 30.

[11] Ibid.

[12] Tirpak, 16.

[13] Ibid., 10.

[14] Rick Foster, Structural Engineer, McDonnell Douglas Aircraft Co., telephone interview with author, 15 February 1996.

[15] Lt Col Herb Foret, F-16 Pilot, interview with author, 18 March 1996.

[16] AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, vol. 2 (Washington, D.C.: GPO, 1992), 253.

[17] David A. Fulghum, "Chechnya Cripples Russian Aviation," *Aviation Week & Space Technology* 143, no. 6 (August 1995): 20-21.

Notes

[18] John A. Tirpak, "Who Needs the F-22?" *Air Force Magazine* 78, no. 4 (April 1995): 29.

[19] *Jane's All The World's Aircraft 1995-96*, ed. Paul Jackson (Alexandria, VA: Jane's Information Group, 1995), 374.

[20] Ibid., 379.

[21] John D. Morrocco, "'Silver Bullet' Option eyed for F-22, SSF," *Aviation Week & Space Technology* 138, no 22 (May 1993): 21-22.

[22] *Jane's Air Launched Weapons 1994*, ed. Duncan Lennox, (Alexandria, VA: Jane's Information Group, 1994).

[23] *Jane's Aircraft*, 379.

[24] Ibid.

[25] David A. Fulghum, "China Pursuing Two-Fighter Plan," *Aviation Week & Space Technology* 143, no. 3 (March 1995): 44.

[26] Arthur Waldron, "Dragon Growling," *National Review* 7, no. 14 (July 1995): 44-45.

[27] Stewart M. Powell, "The China Problem Ahead," *Air Force Magazine* 78, no. 10 (October 1995): 60.

[28] Ibid., 62.

[29] Ibid.

[30] Waldron, 44-45.

[31] Jeffery R. Barnett, *Future War: An Assessment of Aerospace Campaigns in 2010* (Maxwell AFB, AL.: Air University Press, 1996), 71.

[32] Karl P. Magyar, "Conflict in the Post-Containment Era," *War and Conflict Coursebook* (Maxwell AFB, AL.: Air Command and Staff College, 1995), 16-25.

[33] Mark Lorell, et al., "The Gray Threat," *Air Force Magazine* 79, no. 2 (February 1996): 64-65.

[34] Craig Covalt, "Rafale Tests Focus on Weapons, Exports," *Aviation Week & Space Technology* 142, no. 24 (June 1995): 66-67.

[35] Sheila E. Widnall, "Widnall Assess the Force," *Air Force Magazine* 78, no. 4 (April 1995): 34.

[36] Patrick Pexton, "What Americans Favor—And Why," *Air Force Times* 56, no. 7 (18 September 1995): 19.

[37] Benjamin S. Lambeth, *The Winning of Air Supremacy in Operation Desert Storm*, RAND Report P-7837 (Santa Monica, CA.: RAND Corporation, 1993), 35.

[38] Andrew Krepinevich, "Train Wreck Coming," *National Review* 47, no. 13 (July 1995): 42.

[39] Steven Watkins, "Proposed Weapons Spending Dips," *Air Force Times*, 18 March 1996: 34.

[40] Steven Watkins, "General Warns of New Drawdown," *Air Force Times*, 18 September 1995: 21

Notes

[41] Anthony D. Alley, "Forecasting Military Technological Needs," in Dr. Karl P. Magyar et al., eds., *Challenge and Response: Anticipating US Military Security Concerns* (Maxwell AFB, AL.: Air University Press, 1994): 211.

[42] Col John A. Warden III, "Air Theory for the Twenty-first Century," in Dr. Karl P. Magyar et al., eds., *Challenge and Response: Anticipating US Military Security Concerns* (Maxwell AFB, AL.: Air University Press, 1994): 329.

[43] Ibid., 328.

[44] Col David A Deptula, *Firing for Effect: Change in the Nature of Warfare*, (Arlington, VA.: Aerospace Education Foundation, 1995): 18.

[45] Bernard Brodie and Fawn Brodie, *From Crossbow to H-Bomb*, (Bloomington, IN: Indiana University Press, 1973): 38-39.

[46] *Jane's Weapons*, 25.

[47] Ibid.

[48] Ibid.

[49] Thomas A. Keaney and Eliot A. Cohen, *Gulf War Airpower Survey Summary Report* (Washington: GPO, 1993), 245.

[50] John A. Tirpak, "Fogleman Begins His Mission," *Air Force Magazine* 78, no. 3 (March 1995): 26.

[51] Richard P. Hallion, *Storm Over Iraq: Air Power and the Gulf War* (Washington: Smithsonian Institution Press, 1992), 146.

[52] Ibid., 167.

[53] Keaney, 197.

[54] Ibid.

[55] Hallion, 57.

[56] Keaney, 58-59.

[57] Ibid.

[58] Ibid.

[59] Ibid., 61.

[60] *Gulf War Air Power Survey*, vol. 5, *A Statistical Compendium and Chronology*, (Washington: GPO, 1993), 276-277.

[61] Ibid., 584.

[62] "Republic of Iraq," *Jane's Sentinel: The Gulf States 1994* (Alexandria, VA.: Jane's Information Group, 1994), 10-11.

[63] Hallion, 167.

[64] *Gulf War Air Power Survey*, vol. 5, 243.

[65] Joseph L Galloway and Bruce B. Auster, "The Most Dangerous Place to Be," *US News & World Report*, 20 June 1994: 54.

[66] Ibid., 41.

[67] Ibid., 105-108.

Notes

[68] David A. Fulghum, "Pentagon Divided Over Defeating Scuds," *Aviation Week & Space Technology* 140, no. 25 (June 1994): 23.

[69] Benjamin S. Lambeth, "Desert Storm and Its Meaning: The View from Moscow," RAND Report R-4164-AF (Santa Monica, CA.: RAND Corporation, 1992), 35.

[70] Keaney, 197.

[71] Ibid.

[72] Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 12 December 1995.

[73] Stewart M. Powell, "The China Problem Ahead," *Air Force Magazine* 78, no. 10 (October 95): 61.

[74] Fulghum, "Pentagon," 23.

Chapter 4

Modernization: The Ugly

> *Our modernization accounts are continually being raided to pay for other programs within DOD . . . we must stand up to these pressures. Having made the force-structure cuts to fund modernization, we must now stand up to the budgetary challenges to keep those modernization accounts intact.*
>
> —Secretary of the Air Force, Sheila E. Widnall

Introduction

The third pillar of military capabilities is modernization. Modernization is the upgrading of existing systems and the procurement of new systems to ensure long-term readiness. While force structure and readiness are near-term mission indicators, modernization provides the critical long-term roadmap. With diminishing budgets, modernization has moved to the forefront of the debate on future Air Force capabilities.

Modernization planning is extremely difficult. Budget constraints have created an environment critical of any increase in defense spending. With several years of lean defense budgets, there has been keen competition for scarce funds among the three pillars—modernization, readiness and force structure. General Loh, former commander of ACC, confirmed the linkage between readiness and modernization in a recent article. He states, "While technically a modernization issue, failing to buy enough equipment to do a required job becomes a readiness issue. We must continue to insist on a balance among readiness, force structure and modernization. It's not today and some modernization programs are suffering."[1]

In the readiness analysis, a trend was identified that emphasized readiness at the expense of modernization. Consequently, the savings realized from the 1992 to 1994 force structure reductions were not transferred to modernization as originally planned; but used instead for near-term readiness and contingencies.

The literature search and subsequent analysis answered two questions. First, what strategy of subsystem upgrades would enable the F-15C to meet its air superiority obligations into the twenty-first century? Second, is it necessary to buy the F-22 as planned?

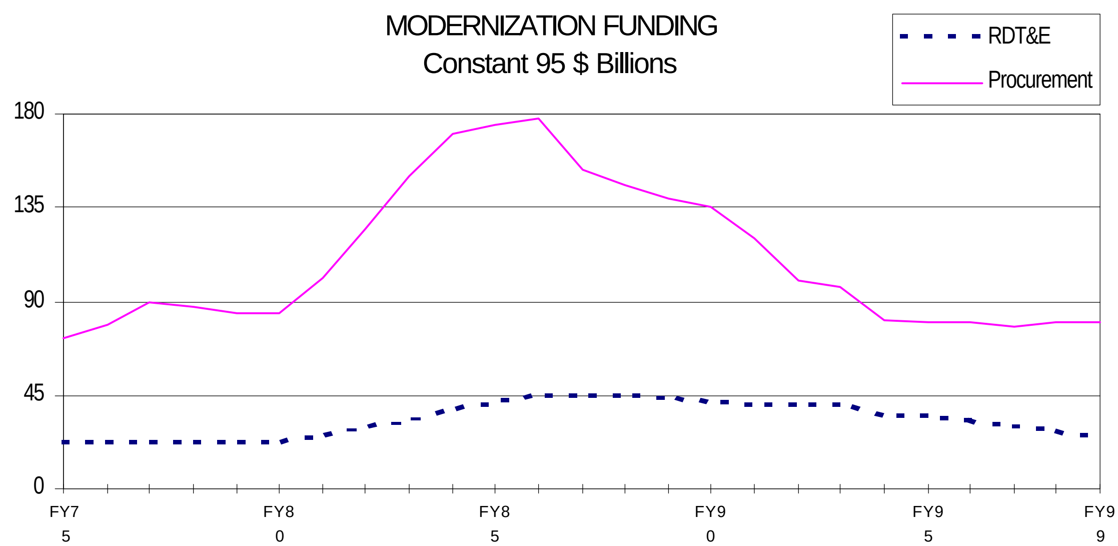
The modernization issue is critical to maintain a technological edge over potential adversaries into the twenty-first century. General Fogleman summarized the importance of the modernization debate when he stated, "If the Air Force doesn't modernize it may be in jeopardy of not being relevant in the next century."[2] The analysis will provide insights into how best to accomplish air superiority modernization.

Literature Search

Modernization Budgets

Why modernize? John A. Tirpak, senior editor for *Air Force Magazine,* states that "modernization is not an option but a necessity."[3] He points out that the modernization issue is highlighted by its affect on other force issues. For example, Tirpak explains the lack of modernization of high demand assets such as the U-2, F-15Es, and RC-135s are areas of particular concern. With fewer aircraft available for worldwide contingencies, the effect on both the maintainers and aircraft is intensified. A similar argument can be made as the result of the Air Force decision to reduce the F-15C force structure.

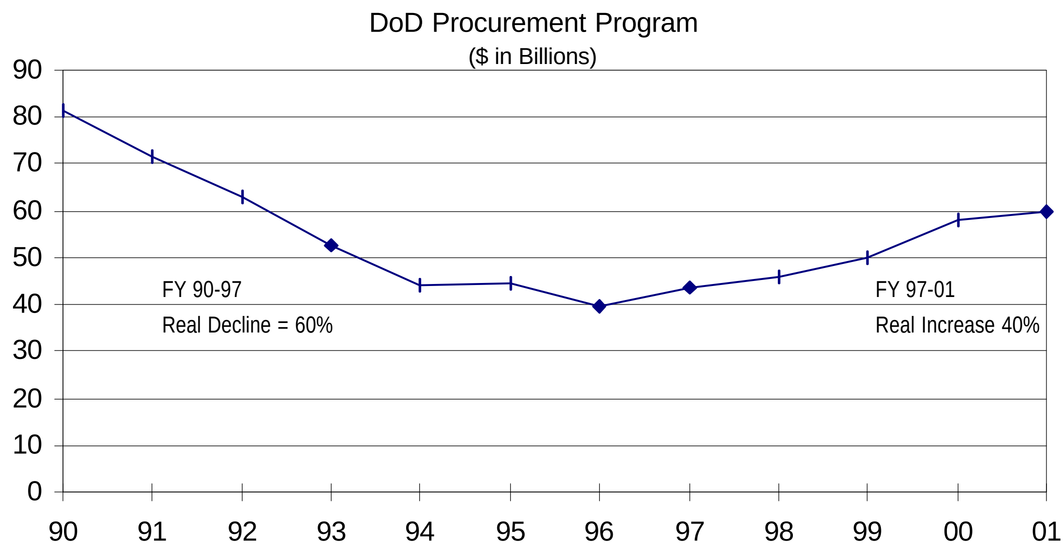
Although near-term readiness has been heavily funded, modernization has experienced record shortfalls. In 1994 the Air Force requested $201 million for F-15 modernization, but only received $77.6 million.[4] There is evidence planners stressed near-term readiness in lieu of modernization. Krepinevich, a noted defense authority, wrote that "the Clinton administration grossly mismatched long-term modernization needs for current short-term readiness dollars."[5] The dividends of the force reduction were not applied to modernization as originally planned. This resulted in the lowest procurement budget since WWII (See fig. 4-1).[6]



Source: House, Department of Defense Appropriations for 1995: Hearings before the Subcommittee of the Committee on Appropriations, 103d Cong., 2d sess., 1994, 175.

Figure 4-1. Modernization Funding

However, there are indications a shift towards increased modernization funding is occurring. Remarks by Secretary of Defense Perry show a renewed emphasis on modernization. "We need to continue to buy some next generation weapons. This is our commitment to the next generation of Americans."[7] General Fogleman stated in a 1995 interview, "We have to get on with [modernization] because the drawdown is essentially over now. So we will now have to start getting that modernization ramping up again."[8] The recently released 1997 budget supports General Fogleman's statements. After six years of declining procurement funding, the Air Force will realize a 40 percent increase in modernization through the year 2001 (See fig. 4-2). This funding situation is going to have a direct impact on the F-22 acquisition and F-15C modernization programs.



Source: *Report of the Defense Science Board Task Force on Aircraft Assessment*, Office of the Under Secretary of Defense for Acquisition, (Washington, D.C.: GPO, 1993), 2.

Figure 4-2. DOD Procurement Program

Because of the fragile funding environment, the Air Force must analyze its priorities. Will there be enough money to buy the required number of F-22s? Will it be necessary to extend the life of the F-15C and possibly rerole it to other missions? Obviously, the budget debate is crucial to the much needed fighter aircraft modernization program.

Finally, the current modernization dilemma is an example of the interrelationship that exists between readiness, force structure and modernization. If budget limitations prevent additional modernization funding, then more force reductions can be expected. The savings from additional force reductions could be earmarked for much needed recapitalization. However, additional force structure reductions would make the two-MRC strategy unsupportable, regardless of the threat.

The needed air superiority modernization program consist of two parts: a subsystem upgrade of the F-15C and procurement of the F-22. The upgrades consist of replacing existing subsystems with new components that improve the reliability and maintainability of the current F-15C. F-22 procurement, although very costly, modernizes and increases force structure.

Reliability Centered Maintenance: Invest not Inspect

Standard military and civilian maintenance procedures use inspection programs as a tool for maintenance management. Although inspections supplement a maintenance program, inspections do not overcome design deficiencies or component service-life limitations. Prior to complex aircraft systems, managers advocated preventative maintenance and inspection programs as methods to control failures.

The Air Transportation Association (ATA) sponsored a study that indicated age limitations and inspection intervals were ineffective in preventing failures.[9] Nowlan and Heap wrote:

> A maintenance policy based exclusively on some max operating age would no matter what the age limit, have little or no effect on the failure rate. Searching studies based on actuarial analysis of failure data suggested that the traditional hard-time policies were, apart from the expense, ineffective in controlling failure rates.[10]

This is important to the current F-15C maintenance programs. The Air Force has followed conventional wisdom by using inspection intervals as a method to ensure safety in aging systems. The short-term solution foregoes component replacement with a reduced inspection interval. Without funding for retrofits, the inspections provide a stop-gap method of maintaining readiness. An alternative is the reliability-centered-maintenance (RCM) program. RCM is a method of long-term component improvement. System upgrades form the foundation of RCM. In their book, *Reliability-Centered Maintenance*, Nowlan and Heap suggest modernizing components within a subsystem. The maintenance manager can then reduce rates of failure dramatically.[11] In addition, the new component would have modifications that could increase resistance to failure.

The recent third stage disk problem in the F-100 engine supports using RCM methods in place of the traditional inspection methods. Prior to 1993, the third stage disk required an inspection every 1500 engine cycles.[12] After a series of mishaps, the inspection interval was reduced as low as 175 cycles.[13] As the cycle interval dropped from 1500 cycles to less than 300 cycles, the failures were not eliminated. However, the increased inspection workload degraded F-15C readiness. The standard inspection interval method was ineffective. According to Nowlan and Heap, inspection intervals do not eliminate systemic design failures. Poor designing of the third stage disk created high cycle fatigue problems.[14] The best recourse was to replace, not inspect the component.

By replacing the third stage disk on specially developed speed-lines, the Air Force was able to retrofit new fan disks in minimal time.[15] The replacement of the disk followed RCM concepts. It allowed an increase in the inspection interval to 1000 cycles (almost two year intervals) and reduced mishaps. Unfortunately, the fan disk inspection had been on-going for four years. The RCM approach would have saved money and labor if it had been implemented from the outset.

Funding is the critical factor of a maintenance plan. The third stage disk problems surfaced in 1993 when the effects of the RSD parts shortfall were at their zenith. Without RSD funds to replace the third stage disk, the alternative was stopgap inspections that were both costly and ineffective. However, replacing the disk rather than shortening the inspection interval would have been economical and effective in the long run.

There is evidence of a shift towards an RCM component improvement program. The F-16 avionics modification program completed in 1992 was an excellent example of RCM. By upgrading the F-16 avionics systems, the workload was reduced 57 percent.[16] Additionally, the F-15C is scheduled for a radar upgrade in 1998. The APG-63V1 will replace one of the largest F-15C maintenance problems. This upgrade is an example of using the RCM maintenance philosophy: reducing reliability problems with component retrofits instead of inefficient inspection programs.

Eagle Generation: Systems Upgrade Program

The Eagle Generation program is an Air Force modernization strategy for the F-15C based on RCM principles. In a 1995 briefing, representatives from McDonnell Douglas identified the Eagle Generation objective as, "a roadmap ensuring F-15 operational effectiveness and sustainability past the year 2020."[17]

Eagle Generation evaluated a series of initiatives for system upgrades and identified six systems to be placed on the fighter configuration plan.[18]

1. APG 63V1 Fire Control Radar.
2. Joint Tactical Information Distribution System.
3. -220E engine upgrade.
4. Secondary power systems.
5. Improved Heads-Up-Display.
6. Advanced close-in air-to-air missile AIM-9X.

The Eagle Generation initiative illustrates the type of RCM strategies that can carry the F-15C into the twenty-first century. [19]

Long-Term Modernization: The F-22

While the Eagle Generation system upgrades do much to improve the near-term readiness of the F-15C, the F-22 is *the* long-term solution to modernization. General Ralston, vice chairman of the Joint Chiefs of Staff asserts:

> The F-22 advanced fighter is absolutely fundamental and remains the top Air Force modernization program . . . the airplane will provide air superiority for US forces for the first half of the twenty-first century.[20]

General Ralstons' statements are reinforced by Secretary Widnall when she wrote in Air Force Magazine, "The initial battle for air superiority may well determine the course of the next MRC . . . this is why the F-22 is our top modernization objective."[21] Secretary Widnall bases her support for the F-22 on her belief the F-15C has lost its technological edge and is at parity with other modern fighters. Also, Widnall cites a growing F-15C vulnerability to improved surface-to-air missiles in a modern air campaign.[22]

With such strong support from key Air Force leaders, should be any doubt 442 F-22s will be procured? There is one very important shortfall in this logic—money. At a time when Congress is dominated by a budget reduction movement, a total program cost of $71.6 billion arouses many critics[23] (See table 4-1).

Table 4-1. F-22 Program Cost

Type Cost	Base-Year	The End Year
Production	$38.7 Billion	$52.5 Billion
Total Program	$58.8 Billion	$71.6 Billion
Unit Fly-Away	$71.6 Million	$98.7 Million

Source: John A. Tirpak, "Perspectives in Air Warfare," *Air Force Magazine* 79, no. 4 (Apr 1996): 24-25.

The program is expensive. Although the F-22 possesses far superior capabilities over any fighter in the world, the per unit cost is almost double that of the F-C. Not surprising, some have contended that an enhanced F-15C with F-22 technologies could provide the needed aircraft at far less cost.

General Loh advocated this concept when he stated, "If the F-22 gets off schedule or over cost, the existing F-15 with F-22 technologies could serve as a competitive alternative."[24] Similarly, a 1994 General Accounting Office (GAO) study reported, "Foreign threats are not mature enough to justify the F-15C replacement".[25] The report called for a delay in first unit Initial Operating Capability from 2003 to 2010.[26] The GAO's call to delay the F-22 supports the 1993 prediction by the Defense Science Board that the F-22 could become "budget-driven rather than event-driven."[27]

General McPeak, former Air Force chief of staff stated, "The services could save an awful lot of money by canceling an entire system program."[28] In a peacetime environment, defense dollars are scarce, especially when the country is in a deficit reduction mode. As one senior Pentagon official stated, "There is no wiggle room in the budget. There are only hard choices left, do I still want to do an F-22 . . . there aren't any easy choices. The easy choices are gone."[29]

If it is so costly, then why modernize? There are three important reasons: force structure improvements; acquisition concerns; and threat considerations. First, 442 F-22s increase the air superiority force structure quantitatively. Indirectly, they also provide much needed relief for the multirole mission.

In the acquisition arena, many analysts are concerned about F-22 delays. Large weapon systems are phased sequentially to eliminate paying several large expenditures simultaneously. The current F-22 production schedule is phased from 1998 to 2008. This places it between the C-17 and the JSF.[30] Any delays in the current F-22 production schedule would overlap it with the JSF and compound modernization funding problems.[31]

Finally, and most importantly, the F-15C technological advantage is eroding. The qualitative advantage once held by the F-15C has been equaled by the Su-27 and will be superseded by the new Russian Multirole Fighter Interceptor (MRI-42) and the Su-35 (See table 4-2).

Table 4-2. F-15C and Russian Interceptor Comparison

AIRCRAFT	STEALTH	THRUST	SUPERCRUISE	FIRST FLIGHT
F-15C	No	24,000 lbs	No	1972
SU-27	No	27,557 lbs	No	1977
SU-35	Low	38,865 lbs	No	1985
MRI-42	Mod	Unknown	Yes	2005-2010
F-22	High	35,000 lbs	Yes	1990

Source: *Jane's All The World's Aircraft 1995-96*, ed. Paul Jackson, (Jane's Information Group, 1995).

Although all three are comparable, the Su-35 (the upgraded version of the Su-27) possesses advantages in armament, thrust-to-weight, and radar. General Loh contends the Su-27 alone can outperform the F-15C at both long and short ranges. In long-range encounters, General Loh states that with the stronger radar the Su-27 "can launch a missile before the F-15C does . . . so, from a purely kinematic standpoint, the Russian fighters outperform the F-15C in the beyond-visual-range fight."[32] The Russians are aggressively pursuing long-range air-to-air missiles in excess of 100 kilometers.[33] These missiles coupled with the long-range, phased-array radar, could dominate the BVR arena.

Unfortunately, the within-visual-range arena is not much better. General Loh feels the AA-11 Archer infrared missile "is better than the best American [infra-red] missile."[34]

General Loh cites the AA-11 off-boresight capabilities, i.e., the ability for the Archer to lock-on without being pointed in the direction of the target, as being superior to American IR missiles. Hopefully, the developmental AIM-9X will close the Russian missile gap.

Although, the Russians have at least equaled the F-15C technologically, the F-22 possesses three capabilities that would reassert US supremacy. First, the F-22 can supercruise (cruise at supersonic conditions without using afterburners). This alone serves as a force-multiplier through increased range, faster time-to-target, and a lower IR signature. Moreover, the advanced avionics in the F-22 improve its offensive and defensive capabilities. Finally, the stealthy design of the F-22 enables it to remain invisible to the powerful radars of the Su-27 and Su-35. This overcomes their biggest advantage, their ability to sense-and-shoot before the F-15C.[35] Also, the stealth factor would help eliminate the surface-to-air missile threat.[36]

However, the F-22 can reassert US superiority only if it is acquired in significant numbers. The Russians studied the USAF's performance in the Gulf War and concluded that stealth and other technologies only make a difference when available in significant numbers.[37] Although expensive, the number of F-22s must not be reduced any lower. The original production plan called for 72 aircraft per year, which was reduced to the current 48 aircraft per year.[38] Lockheed has scheduled production facilities for only 24 per year, anticipating further cuts in the F-22 buy. The total buy provides four wings of F-22s (two wings per MRC).[39] Less than four will further diminish the US ability to fight a peer competitor in a two—MRC. The F-22, purchased in sufficient numbers, would enhance the US ability to support a two-MRC against even peer competitors.

There is almost universal support for the F-22 among senior leaders. Upgrades to the F-15C will make it a legitimate part of the air-to-air mission well into the twenty-first century. However, enemy fighters are rapidly gaining parity; if not superiority. The F-22 is desperately needed to maintain a technological edge. Secretary Perry wrote in his 1995 annual review:

> Many foreign fighters are now at parity with the F-15C. The F-15C is vulnerable to surface-to-air missiles and it may not win the air battle beyond the next decade.[40]

Unfortunately, significant budget pressures, not threat concerns, may dominate the debate over the F-22 procurement. Budget concerns are valid, but the US doctrine depends on air-to-air superiority. *Air Force Manual 1-1* states, "aerospace control . . . the first priority of all aerospace forces."[41] Given budgetary constraints, the challenge is to allocate scarce resources to both F-22 procurement and F-15C modernization.

Modernization Methodology

The literature search investigated the near-term F-15C upgrades and the long-term F-22 procurement. The F-22 procurement issue was thoroughly discussed in both the force structure and modernization literature reviews. Therefore, the modernization analysis investigated only the F-15C near-term modernization. The analysis used two methods: statistical analysis determined the best approach to F-15C upgrades; and a field survey that measured F-15C and F-16 maintenance workloads.

Data Collected

The data came from four sources. WR-ALC depot provided a database of key maintenance indicators that provided subsystem breakrates for the F-15C. Similar data was collected from DRC for the F-16s. Maintainability statistics for the F-15C came from a reliability and maintainability test done at Edwards Air Force Base. The maintainability data from the study provided the maintenance-man-hours (MMH) statistics used in the analysis. In addition, the SA-ALC provided engine reliability data.

Analysis Process

The analysis focused on system modification programs for the F-15C and consisted of two phases: a statistical analysis to identify high maintenance subsystems and a cost-benefit analysis on selected subsystems.

The statistical analysis used both reliability and maintainability statistics. The reliability statistics included subsystem breakrate percentage and number of code threes. Both were organized from highest to lowest and then graphed into a histogram. The combination of breakrate and code three's pointed to the subsystem with the highest number of maintenance actions.

Maintainability was measured using Maintenance Man-Hours per Flight Hour (MMH/FH) metric found in the reliability and maintainability test done at Edwards AFB. Each subsystem was matched with its MMH/FH indicators. The MMH/FH indicators were inserted into the reliability table to provide a method to evaluate maintainability. The engines, radar, and airframe structures were identified through the analysis as the subsystems requiring an upgrade. Finally, a cost-benefit analysis was performed on these three subsystems. The analysis combined the retrofit cost with breakrate, maintenance-man-hours, and MTBF improvements.

Analysis Assumptions

1. There is a direct correlation between breakrate and FMC rates.
2. There is a reliability correlation between F100-PW-220 engines and retrofitted F100-PW-220E engines. The -220E engines are -100 engines that have been upgraded with -220 components. The -220 engine data was used to justify an upgrade from -220 engines to -220E engines.
3. Inflation rates remain reasonably constant. Long-range modernization funding is based on then-year dollars assuming three percent inflation rates.
4. There will be no major changes in current subsystem reliability rates relative to other subsystems as the aircraft ages.
5. RSD funding levels will continue at current rates of nearly 100 percent. The RSD funding directly affects parts availability. This indirectly affects reliability rates.

Analysis: Near-Term and Long-Term Modernization

This chapter was researched at a very opportunistic time. Following the defense drawdown, savings from force-structure cuts were channeled into readiness accounts. Now, the Air Force is on the eve of a refocus back to modernization. For the first time since the drawdown, procurement funds will increase.[42] Gen Fogleman stated:

> We made the decision to cut modernization back so far in order to fund readiness. I don't say that was a bad decision. I just say that tradeoff, and if you made it, then the next place you spend more money is not necessarily on readiness. It's probably on modernization.[43]

The current strategy for recapitalization of the tactical fighter fleet is two-pronged. The long-term plan involves the F-22 procurement and the near-term plan addresses funding to extend the life of the F-15C through the year 2014.

F-22: Do We Really Need It?

No additional analysis is required. The literature reported extensively on the F-22 debate. Bottom line: the F-22 is expensive, but is a critical national requirement. The research cited many excellent reasons for an F-22 buy of no less than 442 aircraft. Dr. Perry stated the best justification for the F-22 when he identified the parity between the

F-15C and other modern fighters.[44] If the US is to gain air superiority quickly and decisively, then we must possess the technology edge. The current modernization plan places the F-22 at the top of the priority list. When asked by Congress for his aircraft funding priorities, General Fogleman replied, "the F-22 fighter, C-17 transport, the F-15E fighter and the F-16 fighter—in that order."[45]

The question is not if, but how many F-22s will the US buy? Again the literature review indicated 442 was adequate: building 72 aircraft per month is too expensive, 24 aircraft per month is too low, and 48 aircraft per month is just right.[46]

F-15C Modernization: What Needs Upgraded?

Not if, but how? The F-15C must operate to at least 2014, even with a full buy of 442 F-22s. The force structure for a two—MRC dictates the extended life of the F-15C into the twenty-first century. With few dollars available for a complete overhaul of aging subsystems, where should the money be spent to best effect the extended life of the F-15C?

Although the literature search provided volumes of information on the F-22 versus F-15C debate, little has been written on a strategy for extending the life of the F-15C. This study addresses the issue using statistical analysis. Statistical analysis was done to determine the subsystems that provide the greatest reliability improvement. In chapter two, the readiness analysis determined FMC rates were most influenced by system breakrates and parts availability. This analysis will address the methods to improve breakrates. In other words, what subsystems would most decrease the rising breakrates?

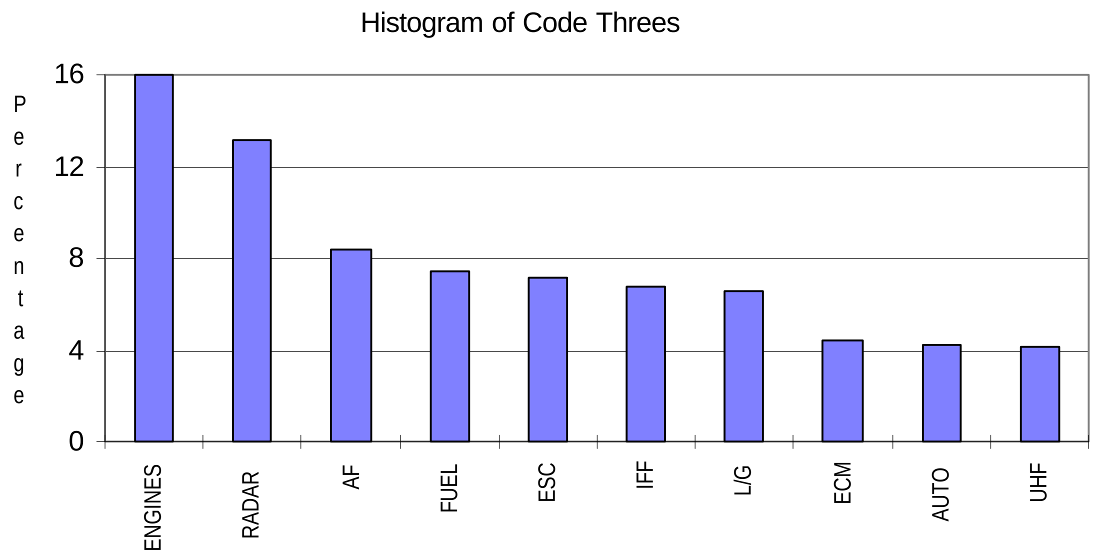
Breakrate is defined as the number of code three maintenance discrepancies per sorties flown. Code three's are pilot-reported discrepancies identifying a particular subsystem as NMC. The highest ten F-15C subsystem breakrates for 1995 are illustrated in table 4-3.

Table 4-3. F-15C Subsystem Breakrate

Subsystem	WOC	MMH/FH	Reported Code 3s	Breakrate (percent)	Percent of Breaks
1. Engines	23	1.50	1261	3.0	16.0
2. Radar	74	1.24	1035	2.5	13.2
3. Airframe	11	1.29	657	1.6	8.4
4. Fuel	46	.62	584	1.4	7.4
5. ECS	41	.26	563	1.3	7.2
6. IFF/Navg	71	.31	538	1.3	6.8
7. Land Gear	13	.43	522	1.2	6.6
8. ECM	76	.15	343	.8	4.4
9. Autopilot	52	.11	328	.8	4.2
10. UHF/Comm	63	.20	321	.8	4.1
Subtotal of Ten	NA	NA	NA	14.7	78.3
FY 95 Totals	NA	NA	NA	18.7	100.0

Source: Jeff Hill, TICARRS Database Manager, WR-ALC/LF, 1990-95 F-15C Maintenance Statistics, 6 Dec 1995.

Two trends are very relevant to the analysis. First, the highest four subsystem breakrates make up 45.5 percent of the total 1995 average breakrate. Likewise, the highest four subsystems make up 45.0 percent of the number of breaks (not rate). These trends are very important because upgrade initiatives should target subsystems that are the greatest sources of code threes. Improving high breakrate contributors will provide the best return on an investment (See fig. 4-3).



Source: Jeff Hill, WR-ALC/Ticarr, 6 Dec 1995.

Figure 4-3. Histogram of Code Threes

In 1995 radar and engines alone accounted for 29.2 percent of the code threes. Almost one—third of all code three breaks can be attributed to only two subsystems from a total of 24 identified in the depot breakrate summary. RCM principles call for subsystem upgrades in at least theses two areas.

The analysis also investigated the subsystem upgrades from a maintainability perspective. Whereas reliability evaluated the number of subsystem failures, maintainability investigates the effort required to repair the maintenance failure. An F-15 reliability and maintainability evaluation completed at the Air Force Flight Test Center, Edwards AFB, was used as the source of maintainability data.[47] The study compared reliability and maintenance tests between the F-15E and the F-15C. Maintainability was measured using average MMH/FH (See table 4-3).

The maintainability trends followed very similar patterns to reliability trends. Within the top five, radar and airframe MMH/FH are the only numbers reversed from the descending rank order in column three. Even then, the difference between radar and airframe was only .05. This can be attributed to RCM theory that relates both reliability and maintainability to the number of components that comprise a system.[48] Simply put, systems that are more complex break more often and are also more difficult to repair.

The most likely candidates for modernization are the three subsystems with the highest breakrates: engines, radar, and airframe structures. Currently, funding has been identified for the radar. In 1998, the Air Force will begin an APG-63 radar retrofit to all F-15Cs with a completion date of 2003. The program will cost $2 million per aircraft with a total program cost of almost $1 billion.[49] The current F-15C radar mean-time-between-maintenance (MTBM) of 30.6 hours should be dramatically reduced.[50]

The rudder is also scheduled for retrofit. Although the main airframe successfully passed the structures test to over 18,000 hours, the secondary structures are failing at an ever increasing rate.[51] Consequently, the Air Force has initiated a retrofit of some of the F-15C's secondary structures: rudder, horizontal stabilators, vertical stabilators, flaps and speed brakes. Many of these surfaces contain composite honeycomb structures which have had durability problems.[52] Table 4-4 depicts the increased depot level repairs on secondary structures.

Table 4-4. F-15C Depot Level Repairs

Structure	1988	1992	1995
Rudders	38	510	576
Horiz Stab	131	298	301
Ailerons	11	166	174
Flaps	44	88	124
Speed Brake	48	94	102

Source: WR-ALC, subject: F-15 Flight Control Replacement Program, 29 Feb 1994.

The significant increases in depot level repairs reveal the maintainers' concern with secondary structures. The sharp rise in secondary structures repairs is elevated because of the high MMH required to repair them.[53]

A roadmap for all secondary structures has been adopted by WR-ALC. Starting in 1997, WR-ALC will replace the rudders for $21.02 million.[54] Authorizations for other secondary structures are not firm. Unfortunately, funding is in serious jeopardy.

The modernization of the F-15C engines is a paradox. On one hand, poor engine maintenance statistics justify their immediate upgrade. Engine code threes makeup 16 percent of all code three discrepancies.[55] On the other hand, engines are the most expensive subsystem to upgrade. The unit cost on a rebuilt F100-PW-100 converted to an F100-PW-220E is $1.5 million. A new F100-PW-220 engine costs over $3 million. If funding becomes available, the plan calls for approximately two squadrons a year (90 engines) for a conversion to the much more reliable -220E.[56] However, with a total cost of $603 million, available funding may preclude the engine conversion.[57]

Although costly, there is strong justification in funding a $603 million upgrade. The upgrade would greatly reduce the unscheduled maintenance. The analysis revealed the engine as the highest contributor to F-15C breakrates, making up 16 percent of all code threes. A program that could reduce the largest maintenance factor on the F-15C provides a great readiness boost.

A comparative analysis indicates substantial gains are possible by modifying existing F100-PW-100 engines to F100-PW-220E engines. Table 4-5 illustrates the historic advantage -220E engines maintain over -100 engines in unscheduled engine removals (UER).

Table 4-5. PW-100-100/220 Comparison

	-100	-220	Percent
UER/1000 EFH	2.62	1.05	59.9
MTBM/EFH	69.2	95.8	27.8
LRU/1000 EFH	4.61	3.02	34.5

Source: Fred Mullis, Pratt & Whitney Customer Service Rep, P&W SA-ALC, USAFE F100 Overview: Mar 1994–Mar 1995 (D042), 12 Dec 1995.

The -220 has a 59.9 percent improvement in UERs and a 27.8 percent improvement in MTBM. Also, the -100 LRUs are replaced at a 34.5 percent higher rate than -220 LRUs. These numbers strongly justify the cost of engine upgrades to a -220E. In fact, depot officials briefed recently that a -220E engine conversion would save $2.4 billion in life cycle costs for the F-15C.[58] One unit reported, after conversion to -220s, that during a three-month period they reduced their MMH by 1099 man-hours (that's 45.8 man-days) on engine removals and installations.[59]

However, the -220E program has a serious shortfall. It is severely short of retrofit modules due to the lean RSD budgets in 1992 to 1994. These problems should be alleviated with recent funding increases. Conversely, the poor reliability rate of the older -100 engine will not diminish. If -220E engines are not funded, the reliability will only degrade further as the -100 engine ages.

In closing, there are strong justifications for upgrading all three of the subsystems with the highest breakrate. However, the likelihood of funding a $1 billion radar upgrade, a $700 million engine upgrade, and a $700 million airframe structures program is extremely unlikely. Although, the $2.4 billion upgrades appear more realistic when compared to the F-22 cost of $71.6 billion.[60]

The initial analysis indicated engines and not radar systems should get the top priority in funding. This is based on a higher engine breakrate, safety issues, and a lower program cost. Further investigation revealed the obsolescence problem in the F-15C radar is projected to increase dramatically. Hence, the funding of the radar upgrade defeats two problems simultaneously—obsolescent parts and low reliability. Experts feel the obsolescence problem will render the F-15C unsupportable if the system is not corrected.[61] Therefore, the decision to fund the radar upgrade ahead of the engine upgrade is justified. Most likely, funding for F-15C upgrades on all three recommended subsystems will not be available. Unfortunately, field maintainers were hoping for all three subsytem upgrades as a relief for their maintenance workload.

Surveys

Modernization is a people issue. Often weapon system modernization is associated with only aircraft. However, modernization is related to reliability and maintainability which directly affects the people who maintain the aircraft. For this reason, maintenance personnel were surveyed from F-15C and F-16 bases to determine any differences in maintenance workload.

Thirteen fighter squadrons were surveyed with over 400 responses (See appendix F). Three questions were subjective in an attempt to determine the maintainer's morale. The other two questions determined actual hours worked over specified time periods.

Question one was used to determine the maintenance workload. Both F-15C and F-16 maintainers felt their workloads were excessive. However, 75 percent of the F-15C maintainers were unhappy with their workloads compared to 61 percent of the F-16 maintainers.

Questions two and three were designed to determine actual hours worked in an attempt to remove subjectivity from the survey responses. Again, the F-15C maintainers are working longer hours. Fifty-six percent of them are working up to six 12 hour shifts per month. Compare this to only 44 percent of the F-16 maintainers working that long. However, only 15 percent of the F-15 maintainers reported not working any weekend shifts, while 24 percent of the F-16 maintainers worked no weekend shifts. These actual figures show the F-15C maintainers are working longer hours and more days to maintain their aircraft.

The final two questions determined the morale of the troops. The F-15C maintainers are definitely more upset, with 92 percent reporting that long hours negatively affect their attitude towards their job. The F-16 maintainers were at 63 percent. Eighty-one percent of the F-15C maintainers reported their morale is affected by their workload. The F-16 numbers are again lower, with a 64 percent rate. These numbers reveal a substantial difference in the way the two groups view their jobs.

These surveys indicate long work hours are required to maintain the F-15C. Long work hours are having a significant impact upon the morale of the troops. F-15C maintainers are almost unanimous in reporting that their attitude toward their job is being negatively affected by the long workdays. While excellent supervision can help with the morale of the troops, the grind of working long hours with little relief will eventually wear down even the most motivated troops. The long-term solution is a robust modernization program as outlined in Eagle Generation.

Recommendation for Modernization

The current modernization dilemma provides no easy decisions. Compounding the problem is uncertainty of who and what are threats in the next century. Regardless, the decisions must be made because the current F-15Cs are losing the technological edge to enemy threats.

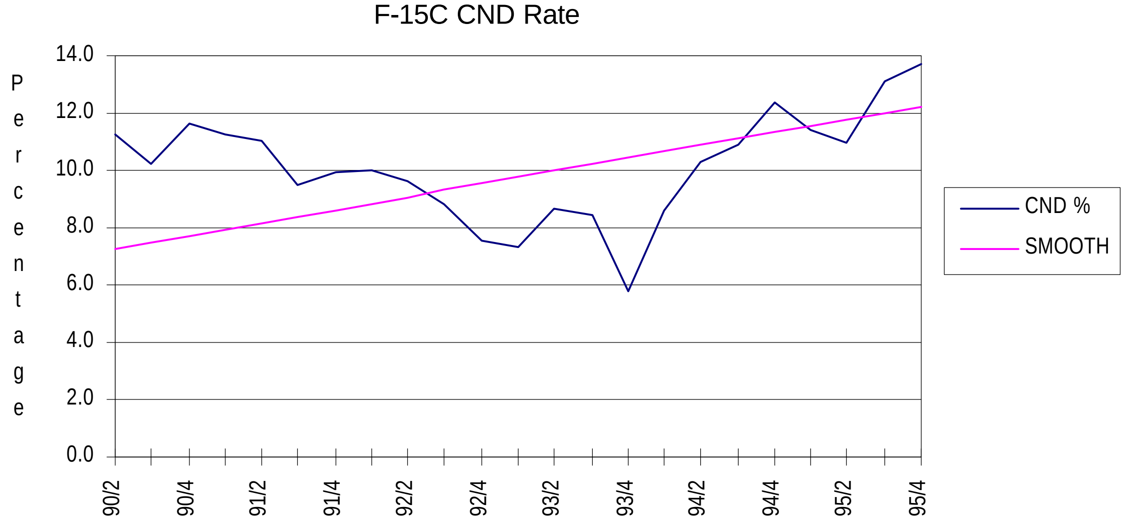
Recommendation One

Fund the F-22 aircraft. Do not delay the current initial-operating-capability date of 2005. Do not reduce the number of aircraft below 442. The threats from potential peer competitors, with Russian Su-35 and MRI-42 aircraft, provide a definite challenge to US air superiority. Also, emerging niche states using gray-threats purchased on the open market will provide a serious challenge to the F-15Cs.

Recommendation Two

Be careful of funding the F-22 with broad force reductions. The total F-22 program cost is $71.6 billion (then-year dollars)—expensive, especially so in a period when the American public demands a balanced budget.[62] One likely source for needed program resources is force reductions; however, if mismanaged this option puts our personnel readiness in jeopardy.

Personnel cuts in 1992 to 1994 used Voluntary Separation Incentive (VSI) programs to reduce personnel force structure. Although admirable, the effects of that program negatively impacted readiness. Large portions of the enlisted force who separated were at the E-5 and E-6 levels, the backbone of intermediate and flightline maintenance. The loss of experienced working-level maintainers seriously affected maintenance units.



Source: Dynamic Research Corp, Lynn Grile, 1995.

Figure 4-4. F-15C CND Rate

The CND rate is an indicator of experience levels. Experienced technicians are able to identify maintenance anomalies much better than inexperienced technicians. The analysis attributed the 1993 to 1995 increase in CND rates to the VSI program and its effect on the backbone of the maintenance force, the staff sergeants and technical sergeants. Although further analysis is beyond the scope of this study, future decisions to cut personnel must be tailored to minimize their impact on the quality and experience levels of our maintenance personnel.

Recommendation Three

Fund F-15C radar, engine, and structures upgrades. The total upgrade of all three is less than $3 billion dollars; but, the improvements will enable the F-15C to fly well into the twenty-first century. The F-15C is currently holding a breakrate of just under 18 percent.[63] If the engines, radar, and structure subsystems are not retrofitted, what will the breakrates be in 2010 when systems are over 30 years old? RCM asserts that replacing low reliability components is a savings in the long term. The analysis supports this philosophy.

Recommendation Four

Relate the F-15C upgrades to quality-of-life issues. DOD policies since 1992 have placed a high premium on readiness and more specifically quality-of-life issues. General Fogleman contends this has happened at "the expense of modernization".[64] But, aren't numerous 12-hour workdays a quality-of-life issue? Senior leaders should be applauded for such noteworthy policies as improving base housing and dormitory facilities—our troops deserve it. However, a $3 billion investment in F-15C upgrades is a quality-of-life issue. The field surveys depicted an F-15C workforce that is under great stress. This paper recommends F-15C system upgrades be marketed not only as aircraft improvement programs, but also as quality-of-life improvements. One survey participant wrote at the bottom of the sheet: "Would someone tell those guys in Washington that a new dorm room isn't any good unless I have time away from the flightline to enjoy it?"

Conclusions

These are tough choices. However, the decisions are critical if the US is to achieve air superiority into the twenty-first century. Senior leaders must make some difficult decisions based on conflicting budgetary, political, and defense constraints. Modernization of the air superiority force is at the center of this debate.

This study determined modernization is one of the most important defense issues as we enter the twenty-first century. Although the previous chapters on readiness and force structure were important, modernization is the lynchpin for the future defense posture.

The analysis identified three issues that are at the forefront of the modernization debate. First, recent Russian advances with the Su-27, Su-35, and planned MRI-42 multirole fighter have challenged the technological advantage once dominated by the F-15C. There is only one viable solution to the growing threat—F-22s.

Second, the statistical analysis revealed the F-15C's declining reliability indicators result primarily from only three subsystems: radar, engines, and secondary structures. A complete retrofit of all three subsystems could be done for less than $3 billion. Compared to the cost of other defense programs, the investment is not large and it would pay great dividends in readiness and force structures.

Finally, modernization is not just an aircraft issue, it is also a people issue. The field surveys indicate stress among the maintainers. F-15C maintainers appear to be under more stress than F-16 personnel. The literature search revealed the decision was made to transfer savings away from modernization in favor of readiness issues. This study concludes modernization of the existing F-15Cs would greatly improve readiness and the quality-of-life or our maintainers.

Can US forces achieve air-to-air superiority quickly and decisively into the twenty-first century? Only with modernized air superiority fighters. In the near-term, modernization should consist of a retrofitting the F-15C radar, engine and structure subsystems. In the long-term, modernization should consist of procuring 442 F-22 fighters as currently scheduled. Dominance of the airspace depends on it.

Notes

[1] John A. Tirpak, "Washington Watch: The Risk of a 'Hollow Future,'" *Air Force Magazine* 78, no. 5 (May 1995): 15

[2] Ibid., 15.

[3] Ibid., 15.

[4] House, *Department of Defense Appropriations for 1995: Hearings before the Subcommittee on the Department of Defense of the Committee on Appropriations*, 103d Cong., 2d sess. (Washington, D.C.: GPO, 1994): 175.

[5] Andrew Krepinevich, "Train Wreck Coming," *National Review* 47, no. 14 (July 1995), 46.

[6] House, 30.

[7] House, 4.

[8] Robert S. Dudney, "The Zero-Warplane Budget," *Air Force Magazine* 78, no. 4 (April 1995): 53.

[9] F. Howard Heap and F. Stanley Nowlan, *Reliability Centered Maintenance*, (Los Altos, CA.: Dolby Access Press, 1978), 3.

[10] Ibid., 4.

[11] Ibid., 75.

[12] HQ ACC/SEF Report, "F100-PW-100 Engine Survey Results," 6 May 1994.

[13] Martin Burisend, Fan Program Manager, SA-ALC, telephone interview with author, 28 Mar 1996.

[14] Briefing, SA-ALC/LR, subject: High Cycle Fatigue Initiative, October 95.

[15] Burisend.

[16] Peter Grier, "Hidden Trends in Readiness Rates," *Air Force Magazine* 76, no. 1 (January 1993): 52-54.

[17] Briefing, McDonnell Douglas Aircraft Co., subject: Eagle Generation Roadmap Brief, 15 March 1995.

[18] Ibid.

[19] Bob Rutter, Eagle Vision Manager, McDonnell Douglas Aircraft Co., telephone interview with author, 29 February 1996.

[20] John A. Tirpak, "Perspectives in Air Warfare," *Air Force Magazine* 79, no. 4 (April 1996): 24-25.

[21] Sheila E. Widnall, "Widnall Assesses The Force," *Air Force* Magazine 78, no. 4 (April 1995): 34.

[22] Ibid., 38.

[23] John A. Tirpak, "Who Needs the F-22," *Air Force Magazine* 78, no. 4 (April 1995): 28.

[24] Bill Sweetman, "USAF Modernization Faces Budget Hurdles," *Interavia/Aerospace World* 50 (June 1995): 69.

[25] "Washington Outlook," *Aviation Week & Space Technology* 140, no. 1 (January 1994): 33.

Notes

[26] Ibid.

[27] *Report of the Defense Science Board Task Force on Aircraft Assessment*, Office of the Under Secretary of Defense for Acquisition (Washington, D.C.: GPO, 1993), 2.

[28] Sweetman, 70.

[29] Vago Muradian, “Wiggle Room is Gone,” *Air Force Times* , 21 February 1994: 19.

[30] Ibid.

[31] William L. Stanley, “Assessing the Affordability of Fighter Aircraft Force Modernization,” *New Challenges for Defense Spending*, ed. Paul K. Davis, (Santa Monica, CA.: RAND Corporation, 1990), 566.

[32] Tirpak, “F-22,” 29.

[33] *Jane’s Air Launched Weapons*, ed. Duncan Lennox, (June 1995): 25.

[34] Tirpak, “F-22,” 29.

[35] Ibid.

[36] William J. Perry, *Annual Report to the President and the Congress* (Washington, D.C.: GPO, 1995), 299.

[37] Benjamin S. Lambeth, *Learning From the Persian Gulf War*, RAND Report P-7850 (Santa Monica, CA.: RAND Corporation, 1993), 11.

[38] Sweetman, 76.

[39] Tirpak, “F-22,” 27.

[40] Perry, 299.

[41] AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, Vol. 2 (Washington, DC: GPO, 1992), 103.

[42] John A. Tirpak, “Washington Watch: The Risk of a ‘Hollow Future,’” *Air Force Magazine* 78, no. 5 (May 1995): 15.

[43] Dudney, 53.

[44] Perry, 229.

[45] John A. Tirpak, “The Risk of a Hollow Force”, *Air Force Magazine* 78, no. 5 (May 1995): 26.

[46] Sweetman, 69.

[47] Carl Ford, *F-15E Reliability and Maintainability Evaluation Final Report*, AFFTC Report TR-89-4F (Edwards AFB, CA.:AFFTC).

[48] F. Howard Heap and F. Stanley Nowlan, *Reliability Centered Maintenance* (Los Altos, CA.: Dolby Access Press, 1978), 102.

[49] Briefing, McDonnell Douglas Aircraft Co., subject: Eagle Vision, September 1994.

[50] Ford.

[51] Rick Foster, Structural Engineer, McDonnell Douglas Aircraft Co., telephone interview with author, 15 February 1996.

[52] Briefing, WR-ALC, subject: F-15 Flight Control Replacement Program, 29 February 1994.

[53] Ibid.

Notes

[54] Ibid.

[55] Jeff Hill, TICARRS Database Manager, WR-ALC/LF, 1990-95 F-15C maintenance statistics, 6 December 1995.

[56] Briefing, subject: FY98 - 03 Propulsion POM Initiatives, October 1995.

[57] Martin Burisend, Fan Program Manager, SA-ALC, telephone interview with author, 28 March 1996.

[58] Briefing, SA-ALC/LR, subject: High Cycle Fatigue Initiative, October 1995.

[59] Col Robert R. Jones, HQ ACC/SEF, "F100-PW-100 Engine Survey Results," 6 May 1994.

[60] Tirpak, "F-22," 28.

[61] Briefing, WR-ALC, subject: Avionics Obsolete Parts, 1995.

[62] Tirpak, "F-22," 28.

[63] Hill.

[64] Dudney, 53.

Chapter 5

Conclusion

The United States Air Force is at a critical point for equipping the air superiority force. Strategically, the global situation is unstable with unconventional threats, emerging states, emerging regional powers and fluctuating budget conditions. But, these dynamic conditions are represented in a single question which is rooted in US airpower doctrine: How does the USAF equip the force needed to achieve air superiority quickly and decisively against any foreign threat into the twenty-first century?

This study examined the role of air superiority by conducting an analysis of the F-15C, presently the primary air superiority fighter in the USAF. The analysis evaluated the F-15C using the three pillars of military capability identified in *Air Force Manual 1-1*: readiness, force structure, and modernization.

This analysis concluded the F-15C currently has a good readiness capability. F-15C units could meet and accomplish their mission from strictly a readiness perspective. But, there are disturbing maintenance indicators which raise some readiness concerns. Since 1992 the fully-mission-capable rate has consistently declined from 83 percent to a recent low of 76.8 percent. Two significant contributing factors are effecting the downward spiraling fully-mission-capable rates. First, a drastic reduction in RSD funding from 1992 to 1994 that funded budgets 60 percent below required levels. The effect on depot level parts was dramatic. Although funding was increased to 100 percent of required levels in 1995, the production lag will continue at least another year. Fortunately senior leaders recognized the problem and full funding was restored.

Second, the breakrate measuring the number of nonmission-capable reports sortie contributed to the declining fully-mission-capable rate. In the last three years, the breakrate hovered around 18 percent. This is substantially higher than the 14 percent levels seen five years ago. This analysis identified the aging-aircraft syndrome as a source of the 18 percent breakrate. Increased unscheduled maintenance failures with F-15C engine components was another contributing factor. However, the study concluded there were no systemic reliability problems that would render the F-15C unready.

This study determined the F-15C force structure, the second pillar of military capabilities, was adequate for a two-MRC with only regional powers. To evaluate the F-15C force structure, a hypothetical model of a two-MRC war against Iran and North Korea was developed. This model was based on operational and logistical data from the Gulf War. The US could meet the two-MRC strategy only if two conditions are present: coalition airpower contributions of approximately 35 percent; and, the MRC threats are limited to niche states and not peer, or even near-peer competitors.

The emerging stealth and precision weapons are propelling the US into a Revolution in Military Affairs. Although air-to-air doctrine is lagging behind the precision—strike theory of air-to-ground, the US must persist in developing long-range standoff air-to-air weapons to compete in the emerging RMA. Lessons from the Gulf War reveal stealth and precision weapons reduce force size significantly. The F-22 stealth capabilities, coupled with a long-rang air-to-air missile, provide the technologies to reach a new level of airpower.

The F-15C cannot meet the air superiority mission for the twenty-first century without the introduction of the F-22 into the force. Both peer and niche states are developing or purchasing advanced fighters that will erode the technological advantage the F-15C has maintained in the last 18 years. In fact, the F-15C's primary role will be to supplement the F-22 as the primary air superiority fighter.

Finally, this study examined the required modernization for air superiority into the twenty-first century. The modernization analysis was organized into two distinct efforts: a near-term analysis for upgrading F-15C subsystems for reliability improvements; and, a long-term evaluation of modernization for the overall air superiority mission.

The near-term analysis consisted of statistical analysis methods. By evaluating 24 F-15C subsystems, the study determined that engines, structures and radar systems possess the poorest reliability and maintainability statistics. The three subsystems were then evaluated in a cost-benefit analysis.

Several key observations were noted. The APG-63 radar, F100-PW-100 engines, and structure upgrades are mandatory. The USAF cannot expect to fly the F-15C to 2014, or beyond, without replacing these subsystems. The total cost of the three retrofits would be under $3 billion. The upgrades would dramatically reduce the current 18 percent breakrate and extend the F-15C service life well beyond 2014.

Additionally, modernization is a people issue. The recent emphasis on quality-of-life issues are admirable, but quality-of-life is more than a new dormitory. Planners have neglected F-15C modernization at the expense of the troops. If people are a vital resource, then we must provide them reliable equipment: an upgraded APG-63V1 radar; a retrofitted F100-PW-220E engine; and new secondary structures. If the USAF does not modernize, readiness will be affected: its people are already losing ground to an 18 percent breakrate. Without subsystem upgrading, the aging process will increase the breakrate beyond the ability to maintain the F-15C.

However, the real concern is long-term modernization. The growing proliferation of advanced fighter technology to both peer and niche states has seriously eroded the F-15C's technological edge. The F-22 is the long-term solution to air superiority. Although it offers many performance advantages, the F-22 provides one advantage that places it above all competitors: outstanding stealth characteristics. The analysis concluded the F-22 is the single system that can simultaneously enhance readiness and force structure. General Fogleman was prophetic: the F-22 is truly a *national* program, not just an Air Force program.

The decisions are difficult. Many variables must be calculated into the final equation. However, air superiority is a cornerstone of US doctrine and there are two solutions to maintain it into the twenty-first century: $3 billion for F-15C upgrades and $71.6 billion for the F-22.

Appendix A

Databases

Table A-1. F-15C Database

QTR	FMC	TNMCM	TNMCS	BRK %	CANN %	BCS %	CND %
90/2	76.6	10.5	10.1	14.6	17.6	17.0	11.2
90/3	83.1	10.5	8.9	12.5	16.9	16.7	10.2
90/4	82.2	11.6	7.2	10.7	14.2	19.8	11.6
91/1	80.4	12.6	8.0	9.7	7.5	14.2	11.3
91/2	81.1	12.1	7.0	17.9	8.0	16.0	11.0
91/3	81.5	11.5	8.0	15.4	13.7	16.6	9.5
91/4	81.9	11.7	8.5	16.4	14.6	15.6	9.9
92/1	82.7	10.9	9.3	19.7	18.5	14.5	10.0
92/2	80.6	12.3	9.3	15.7	12.6	15.4	9.6
92/3	80.2	12.9	9.7	14.0	9.5	16.9	8.8
92/4	78.7	14.0	9.3	16.2	13.9	17.8	7.5
93/1	79.1	13.1	10.9	14.1	15.5	16.0	7.3
93/2	79.8	12.2	9.6	16.9	14.3	15.9	8.7
93/3	82.9	10.2	8.3	17.0	6.4	19.4	8.4
93/4	81.5	10.9	8.3	17.6	3.3	14.5	5.8
94/1	81.6	10.8	8.5	21.5	15.2	15.2	8.6
94/2	75.6	14.4	10.3	18.5	18.1	17.2	10.3
94/3	74.8	14.7	12.4	15.7	14.2	17.4	10.9
94/4	76.7	13.2	12.0	17.3	17.4	13.8	12.4
95/1	79.4	11.2	10.4	17.8	17.9	13.1	11.4
95/2	77.7	12.2	10.4	17.9	16.6	14.4	10.9
95/3	75.6	13.3	10.2	17.5	14.7	12.7	13.1
95/4	75.2	13.4	10.5	17.9	15.1	12.6	13.7

Source: Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 1990-95 F-15C and maintenance statistics, 12 Dec 1995.

Table A-2. F-16C Database (Block 30s)

	FMC Rate	NMCM Rate	NMCS Rate
CY 90	87.8%	5.0%	5.0%
CY 91	84.6%	6.2%	5.4%
CY 92	76.3%	9.4%	6.3%
CY 93	77.0%	10.2%	5.4%
CY 94	71.4%	14.1%	5.3%
CY 95	70.4%	12.9%	4.6%

Source: Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 1990-95 F-16 maintenance statistics, 12 Dec 1995.

Table A-3. F-16C Database (Block 40s)

	FMC Rate	NMCM Rate	NMCS Rate
CY 90	92.0%	2.7%	4.4%
CY 91	91.0%	3.3%	4.1%
CY 92	90.5%	4.1%	4.1%
CY 93	86.7%	5.5%	4.6%
CY 94	79.7%	8.3%	5.7%
CY 95	78.5%	8.3%	5.6%

Source: Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 1990-95 F-16 maintenance statistics, 12 Dec 1995.

Table A-4. F-16C Database (Block 50s)

	FMC Rate	NMCM Rate	NMCS Rate
CY 90	**	**	**
CY 91	**	**	**
CY 92	87.6%	4.5%	6.8%
CY 93	93.6%	3.0%	2.8%
CY 94	87.9%	4.7%	5.7%
CY 95	84.9%	6.1%	5.8%

Source: Lynn Grile, Reliability Analyst, Dynamic Research Corporation, 1990-95 F-16 maintenance statistics, 12 Dec 1995.

Table A-5. TICARRS Data

QTR	FMC	TNMCM	TNMCS	BRK %	CANN %	BCS %	CND %
90/2	76.6	10.5	10.1	14.6	17.6	17.0	11.2
90/3	83.1	10.5	8.9	12.5	16.9	16.7	10.2
90/4	82.2	11.6	7.2	10.7	14.2	19.8	11.6
91/1	80.4	12.6	8.0	9.7	7.5	14.2	11.3
91/2	81.1	12.1	7.0	17.9	8.0	16.0	11.0
91/3	81.5	11.5	8.0	15.4	13.7	16.6	9.5
91/4	81.9	11.7	8.5	16.4	14.6	15.6	9.9
92/1	82.7	10.9	9.3	19.7	18.5	14.5	10.0
92/2	80.6	12.3	9.3	15.7	12.6	15.4	9.6
92/3	80.2	12.9	9.7	14.0	9.5	16.9	8.8
92/4	78.7	14.0	9.3	16.2	13.9	17.8	7.5
93/1	79.1	13.1	10.9	14.1	15.5	16.0	7.3
93/2	79.8	12.2	9.6	16.9	14.3	15.9	8.7
93/3	82.9	10.2	8.3	17.0	6.4	19.4	8.4
93/4	81.5	10.9	8.3	17.6	3.3	14.5	5.8
94/1	81.6	10.8	8.5	21.5	15.2	15.2	8.6
94/2	75.6	14.4	10.3	18.5	18.1	17.2	10.3
94/3	74.8	14.7	12.4	15.7	14.2	17.4	10.9
94/4	76.7	13.2	12.0	17.3	17.4	13.8	12.4
95/1	79.4	11.2	10.4	17.8	17.9	13.1	11.4
95/2	77.7	12.2	10.4	17.9	16.6	14.4	10.9
95/3	75.6	13.3	10.2	17.5	14.7	12.7	13.1
95/4	75.2	13.4	10.5	17.9	15.1	12.6	13.7

Source: Jeff Hill, TICARRS Database Manager, WR-ALC/LF, 1990-95 F-15C maintenance statistics, 6 Dec 1995.

Appendix B

Regression Model

Table B-1. ISP Program Data

Variable	Coefficient	Standard Error	T-Test	Significant	P-Value
a	107.6817	3.315312	32.480	Y	.000
TNMCM	-1.255047	.2830776	-4.434	Y	.000
TNMCS	-.6484008	.2448562	-2.648	Y	.018
BRK	-.1914386	.1020022	-1.877	N	.079
CND	-.3039332	.1607829	1.890	N	.077
SSD	-1.989197	1.176025	-1.691	N	.110
O&M	-.150731	.07030765	-2.144	Y	.048

Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

The critical t-value for d.f. = 16 and alpha = .0500 is 2.11991.

Std dev of reg = 1.15899, R = .929, R-Sqrd = .863, Adj R-Sqrd = .811
F-test = 16.773, p-value = .0000, F value from table (alpha = .05) = 2.74
Observations = 23.0 Degrees of freedom for numerator = 6, for denominator = 16

Table B-2. Regression Analysis: Correlation Between Regression Coefficients

Coeff	Constant	TNMCM	TNMCS	BRK	CND	SSD	O&M
Constant	1.000	-.709	.196	.603	.110	-.336	-.374
TNMCM	-.709	1.000	.626	.325	-.251	.470	.405
TNMCS	.196	-.626	1.000	-.375	-.007	-.335	-.236
BRK	-.603	.325	.375	1.000	-.005	.261	.298
CND	-.110	-.251	-.007	-.005	1.000	-.504	.020
SSD	-.336	.470	-.335	.261	-.504	1.000	.225
O&M	-.374	.405	-.236	.298	.020	.225	1.000

Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

Table B-3. Regression Model Input Database

	FMC	TNMCM	TNMCS	BRK	CND	SSD	O&M	Y
90/2	76.6	10.5	10.1	14.6	11.2	1	-0.9	79.90226
90/3	83.1	10.5	8.9	12.5	10.2	1	-0.9	81.3863
90/4	82.2	11.6	7.2	10.7	11.6	1	-0.9	81.02711
91/1	80.4	12.6	8	9.7	11.3	0.34	-4.2	81.34625
91/2	81.1	12.1	7	17.9	11	0.34	-4.2	81.14355
91/3	81.5	11.5	8	15.4	9.5	0.34	-4.2	82.18268
91/4	81.9	11.7	8.5	16.4	9.9	0.34	-4.2	81.29445
92/1	82.7	10.9	9.3	19.7	10	0.61	-11	81.60552
92/2	82.2	12.3	9.3	15.7	9.6	0.61	-11	80.73578
92/3	80.2	12.9	9.7	14	8.8	0.61	-11	80.29198
92/4	78.7	14	9.3	16.2	7.5	0.61	-11	79.14474
93/1	79.1	13.1	10.9	14.1	7.3	0.42	1.4	78.20853
93/2	79.8	12.2	9.6	16.9	8.7	0.42	1.4	79.21946
93/3	82.9	10.2	8.3	17	8.4	0.42	1.4	82.64451
93/4	81.5	10.9	8.3	17.6	5.8	0.42	1.4	82.44134
94/1	81.6	10.8	8.5	21.5	8.6	0.4	-4.1	81.70835
94/2	75.6	14.4	10.3	18.5	10.3	0.4	-4.1	76.08069
94/3	74.8	14.7	12.4	15.7	10.9	0.4	-4.1	74.6962
94/4	76.7	13.2	12	17.3	12.4	0.4	-4.1	76.07593
95/1	79.4	11.2	10.4	17.8	11.4	1	-5.5	78.84918
95/2	77.7	12.2	10.4	17.9	10.9	1	-5.5	77.72696
95/3	75.6	13.3	10.2	17.5	13.1	1	-5.5	75.88401
95/4	75.2	13.4	10.5	17.9	13.7	1	-5.5	75.30505

Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

Appendix C

Regression Analysis Data

C.1 F-Test (Determine Model Statistical Significance).

1. From Data Output, $R^2 = .863$.
2. Entering R^2 table of critical values for 23 observations and six independent variables, critical value = .718.
3. Perform F-Test is $R^2 \geq$ critical value. If so very highly significant within .1%.
   863 > .718 = Yes, *very highly significant*.

C.2 Outputted values exceeding critical values of 2.074 are determined with 95% significant as a single variable. See table 9.1.1 from *Practical Business Statistics*.

n=23
DOF=22
95% = Confidence Level
Critical Value = 2.074

Table C-1. F-Test Data

TNMCM	|-4.434|	2.074	Yes
TNMCS	|-2.648|	2.074	Yes
BRK	|-1.877|	2.074	No
CND	|-1.890|	2.074	No
SSD	|-1.691|	2.074	No
O&M	|-2.144|	2.074	Yes

Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

Table C-2. Regression Analysis

Variable	Coefficient	T-Test	.050 Significance	P-Value
a	107.6817	32.480	Y	.000
TNMCM	-1.255047	-4.434	Y	.000
TNMCS	-.6484008	2.648	Y	.018
BRK	-.1914386	-1.877	N	.079
CND	-.3039332	-1.890	N	.077
SSD	-1.989197	-1.691	N	.110
O&M	-.150731	-2.144	Y	.048

Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.
Dependent Variable: FMC

Std dev of reg = 1.15899, R = .929, R-Sqrd = .863, Adj R-Sqrd = .811
F-test = 16.773, p-value = .0000, F value from table (alpha = .05) = 2.74
Observations = 23 Degrees of freedom for numerator = 6, for denominator = 16

Using this data, these three models validations were completed:

1. The F-test was completed and provide the overall model significance as within .1%, in the "very highly significant" category.
2. Likewise, the t-test was completed and provided as output in column 4. The three independent variables TNMCM, TNMCS and O&M were determined individually significant (see appendix 8.2). Note that although breakrate and CND were below critical value of 2.074, they were relatively close. This lends to the high overall model rating from the F-Test.
3. The last column provides the values for the P-value test. Any value below .05 is considered within conventional range of 5 percent variability with a 95 percent confidence level. Although, some individuals feel 10 percent (< .1) is readily acceptable.

Overall, the regression model easily conforms within acceptable confidence levels. For the three variables that were not significant, they represent condition of multi-colinearity because of similar values measurement. Now an analysis of relationships between the six variables and the resultant FMC Rate can be completed.

C.4 Prediction Equation.

From the regression analysis, the following coefficients with corresponding standard errors for each coefficient:

Table C-3. Prediction Equation

Variable	Coefficient	Standard Error
a	107.6817	3.315312
TNMCM	-1.255047	.2830776
TNMCS	-.6484008	.2448562
BRK	-.1914386	.1020022
CND	-.3039332	.1607829
SSD	-1.989197	1.176025
O&M	-.150731	.07030765

Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

Using the standard regression equation (981-B):

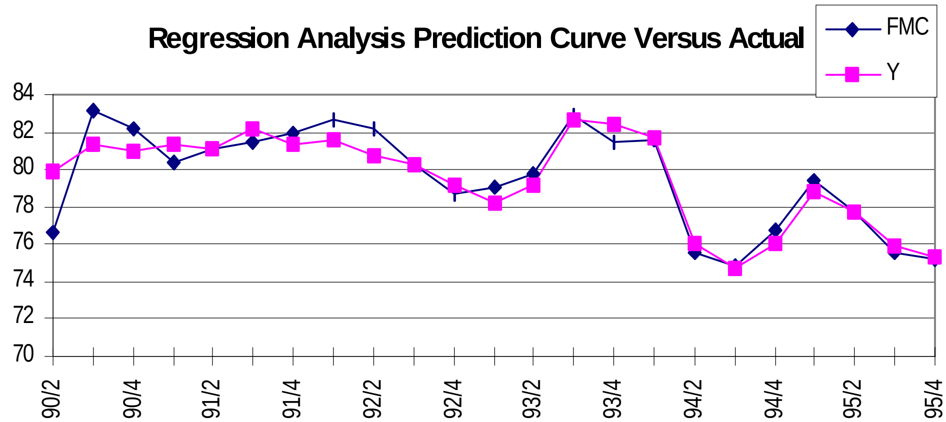
$$Y = a+b_1x_1+b_2x_2+ . . . +b_px_p$$

Forming the following prediction or regression equation for the model of FMC as a function of TNMCM, TNMCS, BRK, CND, SSD and O&M.

FMC = 107.7 - 1.3 (TNMCM) - .6 (TNMCS) - .2 (BRK) - .3 (CND) - 2.0 (SSD) - .1 (O&M)

This equation will predict FMC Rate based on data from 1990-1995 within above specified standards of error.

The following plots illustrate the close approximations between actual and prediction curves.

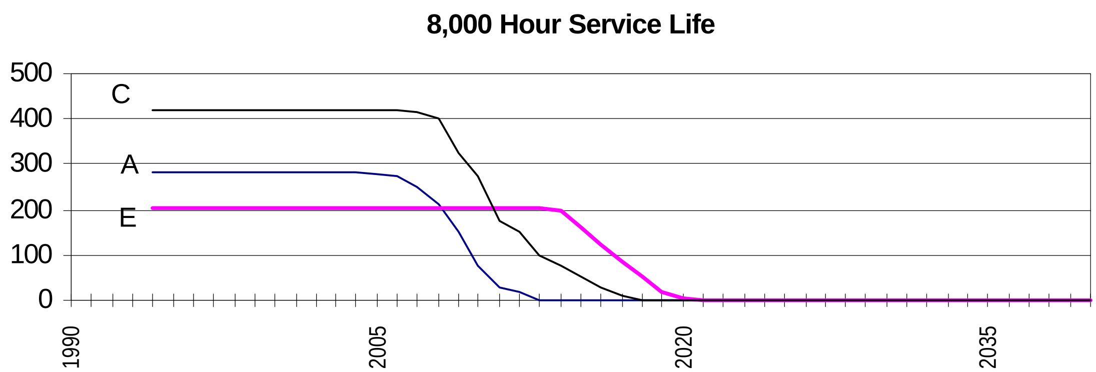


Source: ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

Figure C-1. Regression Analysis Prediction Curve Versus Actual

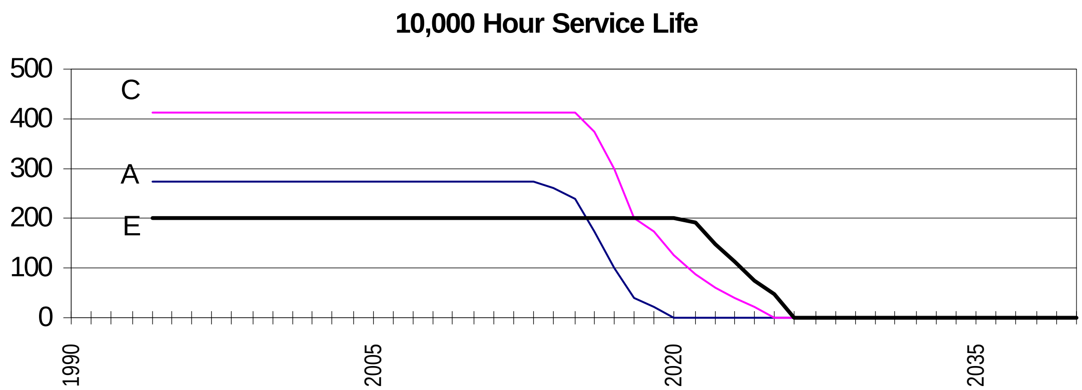
Appendix D

F-15 Service Life



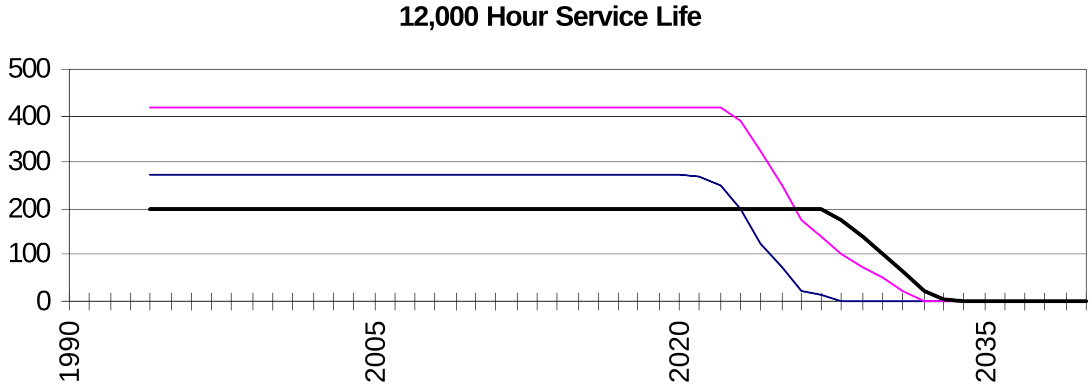
Source: Rick Foster and Ron Mellere, *Aerospace Digest* 41, no. 3 (Summer 1994).

Figure D-1. 8,000 Hour Service Life



Source: Rick Foster and Ron Mellere, *Aerospace Digest* 41, no. 3 (Summer 1994).

Figure D-2. 10,000 Hour Service Life



Source: Rick Foster and Ron Mellere, *Aerospace Digest* 41, no. 3 (Summer 1994).

Figure D-3. 12,000 Hour Service Life

Appendix E

Two MRC Sortie Calculation

Aircraft required to meet 30 day sorties based on average of 120 OCA and CAP sorties per day. The 120 sorties per day is worst case. In the Gulf War, USAF F-15Cs flew 66 percent of OCA and CAP missions averaging 138 sorties per day for the first three days of the war; 98 sorties per day after air supremacy was declared on 27 January; 98 sorties per day over the 42 day air war (17 Jan–28 Feb). The calculations were based on the following assumptions:

Calculate number aircraft to meet 120 sorties per day for 30 days:

Assume:

1. Assume 80.0 percent MC rate. In Gulf, FMC rates rose to 93.6 percent average. For 1995 peacetime, MC rate was 80.4.
2. Assume adequate parts availability.
3. Assume adequate base defense and availability. Should evacuation of air bases on Korean peninsula be necessary, operations would carry on from bases at Kadena and Misawa AB, Japan. This would affect sortie duration length and subsequent number of aircraft required.
4. Assume worst-case air loss attrition of two percent for first 10 days of war. In Gulf, zero percent attrition rate was achieved by F-15Cs.
5. Assume five-percent abort rate (standard). In Gulf, abort rate was much lower.
6. Assume a three-percent attrition loss to enemy air operations for first 10 days of war. All lost aircraft replaced with attrition aircraft.

7. Korea/Iran calculations (Data Assumed):
    a. available F-15C less NMC and aborts:
       100 F-15C in theater (not including attrition fill)
       <u>.80</u> assumed MC rate
       80 available A/C per day for launch
       <u>-4</u> daily abort loss based on 5 percent abort rate
       76 aircraft launch
    b. Average sorties per flying:
       120/76 = 1.58 sorties per flyer per day
    c. Total sorties in 30 day period:
       30 days × 120 sorties = 3600 total sorties (30 days)
    d. Total loss aircraft at 3 percent attrition for first 10 days of war:
       120 sorties/day × 30 days × .03 = 35 A/C
8. 1991 Gulf War calculations.
    a. Available F-15C less NMC and aborts:
       100 F-15C in theater
       <u>.93</u> FMC rate
       93 aircraft available
       <u>-2</u> less abort A/C of 2 percent
       91 aircraft available
    b. Average sortie per flyer:
       108/91 = 1.19
    c. Total sorties 42 day period: 4558 USAF OCA/CAP
       Not calculated, obtained GWAPS pg. 197.
    d. Total attrition due to enemy operations: 0 percent
       Not calculated, obtained GWAPS pg. 197.

Appendix F

Survey Questionnaires

F-15 Questionnaire

On Maintaining My Weapon System

The following 5 questions deal with the maintenance workload for F-15 maintainers (E-6 and below). The results of this survey will be summarized in an Air Command and Staff College research paper.

Note: At no time will individual maintainers, their squadrons, or their wings be identified individually. The results will be summarized by weapon system only, e.g., F-16 workloads vs. F-15 workloads.

(Circle the best response):

1. The F-15 maintenance workload is excessive requiring many long duty days and weekend duty.

   Strongly Disagree **Disagree** **Undecided** **Agree** **Strongly Agree**

2. In the past four weeks I've worked ___ 12-hour shift workdays.

   (None) **(1-3)** **(4-6)** **(7-9)** **(10-12)** **(13 or more)**

3. In the past eight weeks I've worked ___ weekends.

   (None) **(1-2)** **(3-4)** **(5-6)** **(7-8)**

4. The length of my workdays affect my attitude toward my job.

   Strongly Disagree **Disagree** **Undecided** **Agree** **Strongly Agree**

5. The morale of my unit is negatively affected by the F-15 maintenance workload.

   Strongly Disagree **Disagree** **Undecided** **Agree** **Strongly Agree**

F-16 Questionnaire

On Maintaining My Weapon System

The following 5 questions deal with the maintenance workload for F-16 maintainers (E-6 and below). The results of this survey will be summarized in an Air Command and Staff College research paper.

Note: At no time will individual maintainers, their squadrons, or their wings be identified individually. The results will be summarized by weapon system only, e.g., F-16 workloads vs. F-15 workloads.

(Circle the best response):

1. The F-16 maintenance workload is excessive requiring many long duty days and weekend duty.

   Strongly Disagree **Disagree** **Undecided** **Agree** **Strongly Agree**

2. In the past four weeks I've worked ___ 12-hour shift workdays.

   (None) **(1-3)** **(4-6)** **(7-9)** **(10-12)** **(13 or more)**

3. In the past eight weeks I've worked ___ weekends.

   (None) **(1-2)** **(3-4)** **(5-6)** **(7-8**)

4. The length of my workdays affect my attitude toward my job.

   Strongly Disagree **Disagree** **Undecided** **Agree** **Strongly Agree**

5. The morale of my unit is negatively affected by the F16 maintenance workload.

   Strongly Disagree **Disagree** **Undecided** **Agree** **Strongly Agree**

Bibliography

Abell, John B. and H. L. Shulman. *Evaluations of Alternative Maintenance Structures*, RAND Report R-4205-AF. Santa Monica, CA: RAND Corporation, 1992.

AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, vol. 2. Washington, D.C.: GPO, 1992.

Alley, Anthony D. "Forecasting Military Technological Needs," in Dr. Karl P. Magyar et al., eds., *Challenge and Response: Anticipating US Military Security Concerns*. Maxwell AFB, AL.: Air University Press, 1994.

Barnett, Jeffery R. *Future War: An Assessment of Aerospace Campaigns in 2010*. Maxwell AFB, AL.: Air University Press, 1996.

Bolds, Lt Col Ted. "Maintaining the Defense Industrial Base." Air War College Paper, 2 May 1994.

Brodie, Bernard, and Fawn Brodie. *From Crossbow to H-Bomb*. Bloomington, IN.: Indiana University Press, 1973.

"The CBO's Air Force." *Air Force Magazine* 78, no. 3 (March 1995): 28-33.

Chapman, Suzann. "Aerospace World." *Air Force Magazine* 78, no. 3 (March 1995): 11-20.

Cohen, I. K., R. A. Pyles, and R. A. Eden. *Lean Logistics: A More Responsive, Robust, and Affordable System*, RAND Report DRR-630-AF. Santa Monica, CA.: RAND Corporation, 1994.

Covalt, Craig. "Rafale Tests Focus on Weapons, Exports." *Aviation Week & Space Technology* 142, no. 24 (June 1995): 66-67.

Deptula, Col David A. *Firing for Effect: Change in the Nature of Warfare*. Arlington, VA.: Aerospace Education Foundation, 1995.

Dudney, Robert S. "Aerospace World." *Air Force Magazine* 78, no. 1 (January 1995): 12-21.

Dudney, Robert S. "The Zero-Warplane Budget." *Air Force Magazine* 78, no. 4 (April 1995): 52-54.

Eden, Rick, et al. *Reinventing the DOD Logistics System to Support Military Operations in Post-Cold War Era*, RAND Report. Santa Monica, CA.: RAND Corporation, 1994.

Ford, Carl. *F-15E Reliability and Maintainability Evaluation Final Report*, AFFTC Report TR-89-4F. Edwards AFB, CA.: AFFTC, 1989.

Fulghum, David A. "Chechnya Cripples Russian Aviation." *Aviation Week & Space Technology* 143, no. 6 (August 1995): 20-21.

Fulghum, David A. "China Pursuing Two-Fighter Plan." *Aviation Week & Space Technology* 143, no. 3 (March 1995): 44.

Fulghum, David A. "Congress Blocks Aim-9X, Triggers Six-Month Delay." *Aviation Week & Space Technology* 140, no. 14 (April 1994): 28.

Fulghum, David A. "Pentagon Divided Over Defeating Scuds." *Aviation Week & Space Technology* 140, no. 25 (June 1994): 23.

Galloway, Joseph L., and Bruce B. Auster. "The Most Dangerous Place to Be." *US News & World Report*, 20 June 1994: 54.

Gentsch, Eric L., and Donna J. S. Peterson. *A Method for Industrial Base Analysis: An Aerospace Case Study*. Bethesda, MD: Logistics Management Institute, 1994.

Girardini, Kenneth, et al. *Improving DOD Logistics*, RAND Report DB-148-CRMAF. Santa Monica, CA.: RAND Corporation, 1995.

Grier Peter. "Hidden Trends in Readiness Rates." *Air Force Magazine* 76 no. 1 (January 1993): 52-55.

Grier, Peter. "Snapshots of a Force on the Move." *Air Force Magazine* 78, no. 6 (June 1995): 58-62.

Grile, Lynn, Reliability Analyst. "1990-95 F-15C and F-16 maintenance statistics." Dynamic Research Corporation, 12 December 1995.

Gulf War Air Power Survey, vol. 5, *A Statistical Compendium and Chronology*. Washington, D.C.: GPO, 1993.

Hallion, Richard P. *Storm Over Iraq: Air Power and the Gulf War*. Washington, D.C.: Smithsonian Institution Press, 1992.

Heap, F. Howard and F. Stanley Nowlan. *Reliability Centered Maintenance*. Los Altos, CA.: Dolby Access Press, 1978.

Hill, Jeff, TICARRS Database Manager. "1990-95 F-15C maintenance statistics." WR-ALC/LF, 6 December 1995.

Holley, I. B. *The United States Army in World War II, Special Studies, Buying Aircraft: Matériel Procurement for the Army Air Forces*. Washington, D.C.: Office of the Chief of Military History, 1964.

Hollingsworth, Ben. memorandum for record, subject: RSD/SSD Funding. WR-ALC/LFCF, 13 December 1995.

House. *Department of Defense Appropriations for 1995: Hearings before the Subcommittee on the Department of Defense of the Committee on Appropriations*, 103d Cong., 2d sess. Washington, D.C.: GPO, 1994.

House. *National Defense Authorization Act for Fiscal Year 1995: Hearings before the Subcommittee on Military Readiness of the Committee on National Security*, 103d Cong., 1st sess. Washington, D.C.: GPO, 1994.

ISP version 4.6, Lincoln Systems Corporation, Westford, MA.

Jane's Air Launched Weapons 1994. Ed. Duncan Lennox. Alexandria, VA: Jane's Information Group, 1994.

Jane's All The World's Aircraft 1995-96. Ed. Paul Jackson. Alexandria, VA: Jane's Information Group, 1995.

Jones, Col Robert R., "F100-PW-100 Engine Survey Results." HQ ACC/SEF, 6 May 1994.

Keaney, Thomas A., and Eliot A. Cohen. *Gulf War Air Power Survey Summary Report*. Washington, D.C.: GPO, 1993.

Krepinevich, Andrew. “Train Wreck Coming.” *National Review* 47, no. 14 (July 1995): 42-46.

Lambeth, Benjamin S. *Desert Storm and Its Meaning: The View from Moscow*, RAND Report R-4164-AF. Santa Monica, CA.: RAND Corporation, 1992.

Lambeth, Benjamin S. *Learning From the Persian Gulf War*, RAND Report P-7850. Santa Monica, CA.: RAND Corporation, 1993.

Lambeth, Benjamin S. *The Winning of Air Supremacy in Operation Desert Storm*, RAND Report P-7837. Santa Monica, CA.: RAND Corporation, 1993.

Lorell, Mark, et al. “The Gray Threat.” *Air Force Magazine* 79, no. 2 (February 1996): 64-65.

Magyar, Karl P. “Conflict in the Post-Containment Era.” War and Conflict Coursebook, Maxwell AFB, AL.: Air Command and Staff College, 1995, 16-25.

McMahon, Gary C. “Air Force Logistics Doctrine: Where is it?” Air War College Thesis, Maxwell AFB, AL, 1985.

Mills, Maj K., ACC/LGF15. memorandum to Col Belisle, ACC/LGF. 22 August 1995.

Mills, Maj K., ACC/LGF15. memorandum to Col Bjoring, ACC/LGF. 12 May 1995.

Morrocco, John D. “‘Silver Bullet’ Option eyed for F-22, SSF.” *Aviation Week & Space Technology* 138, no 22 (May 1993): 21-22.

Mullis, Fred, Pratt & Whitney Customer Service Rep, P&W SA-ALC. “USAFE F100 Overview: March 1994-March 1995 (DO42),” 12 December 1995.

Muradian, Vago. “Wiggle Room is Gone.” *Air Force Times* 54, no. 29 (21 February 1994): 19.

Nowlan, F. Stanley, and F. Howard Heap. *Reliability Centered Maintenance*. Los Altos, CA.: Dolby Access Press, 1978.

Perry, William J. *Annual Report to the President and the Congress*. Washington, D.C.: GPO, 1995.

Pexton, Patrick. “What Americans Favor—And Why.” *Air Force Times*, 18 September 1995: 19.

Powell, Stewart M. “The China Problem Ahead,” *Air Force Magazine* 78, no. 10 (October 1995): 60-63.

Report of the Defense Science Board Task Force on Aircraft Assessment. Office of the Under Secretary of Defense for Acquisition. Washington, D.C.: GPO, 1993.

“Republic of Iraq,” *Jane’s Sentinel: The Gulf States 1994*. Alexandria, VA: Jane’s Information Group, 1994: 10-11.

Siegel, Andrew F. *Practical Business Statistics*. Burr Ridge, IL.: Irwin, 1994.

Stanley William L. “Assessing the Affordability of Fighter Aircraft Force Modernization.” *New Challenges for Defense Spending*. Ed. Paul K. Davis. Santa Monica, CA: RAND Corporation, 1990.

Sweetman, Bill. “USAF Modernization Faces Budget Hurdles.” *Interavia/Aerospace World* 50 (June 1995): 69.

Syrett, David. “Northwest Africa 1942-1943,” in Benjamin Franklin Cooling, ed., *Case Studies in the Achievement of Air Superiority*. Washington, D.C.: Center for Air Force History, 1994.

Tirpak John A. “Who Needs the F-22.” *Air Force Magazine* 78, no. 4 (April 1995): 24-29.

Tirpak, John A. “Fogleman Begins His Mission.” *Air Force Magazine* 78, no. 3 (March 1995): 22-26.

Tirpak, John A. “Perspectives on Air Warfare.” *Air Force Magazine* 79, no. 4 (April 1996): 24-28.

Tirpak, John A. “Washington Watch: The Risk of a ‘Hollow Future.’” *Air Force Magazine* 78, no. 5 (May 1995): 15-19.

Tirpak, John. “Hollow Pockets.” *Air Force Magazine* 77, no. 12 (December 1994): 52-56.

Towell, Pat. “GOP Faces a Clash of Priorities with its Bid to Boost Readiness.” *Defense & Foreign Policy*, 14 January 1995: 168.

“The US Air Force in Facts and Figures.” Air Force Magazine 78, no. 5 (May 1995): 35-55.

Waldron, Arthur. “Dragon Growling.” *National Review* 7, no. 14 (July 1995): 44-45.

Warden, Col John A., III. “Air Theory for the Twenty-first Century,” in Dr. Karl P. Magyar et al., eds., *Challenge and Response: Anticipating US Military Security Concerns*. Maxwell AFB, AL.: Air University Press, 1994, 311-332.

“Washington Outlook.” *Aviation Week & Space Technology* 140, no. 1 (Jan 1994): 33.

Watkins, Steven. “General Warns of New Drawdown.” *Air Force Times*, 18 September 1995: 3.

Watkins, Steven. “Proposed Weapons Spending Dips.” *Air Force Times*, 18 March 1996: 34.

Widnall, Sheila E. “Widnall Assesses the Force.” *Air Force Magazine* 78, no. 4 (April 1995): 30-36.